UNIVERSITY OF SOUTHAMPTON

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Electronics and Computer Science

Computer Support for Self-Regulated Student Learning in Individual Project-Based Settings

by

Till Rebenich

Thesis for the degree of Doctor of Philosophy

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ABSTRACT

FACULTY OF PHYSICAL AND APPLIED SCIENCES
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COMPUTER SUPPORT FOR SELF-REGULATED STUDENT LEARNING IN INDIVIDUAL PROJECT-BASED SETTINGS

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Higher education increasingly emphasises the importance of learner self-regulation and autonomy. Self-regulated learners are active participants in their own learning and employ strategies for sustaining motivation, metacognitive thinking, and self-monitoring. This work identifies four central aspects which are investigated in an individual project-based learning setting, namely motivation, time management, progress awareness, and monitoring. Monitoring is the key driver of learner self-regulation. Time management has proven to enhance perceived control over time, health, and academic achievement. Progress awareness supports learner self-observation and self-evaluation. Finally, monitoring is the process of generating feedback both internally (own feedback) and externally (from others). In this work, a 17-week quasi-experimental study involving 378 participants was conducted, preceded by a less successful trial. The study employed a web-based monitoring system, combined with a monitoring scheme in the context of Master of Science (MSc) summer projects in the School of Electronics and Computer Science at the University of Southampton, implementing a set of features for each learning aspect. In the monitoring scheme, monitors met with groups of students weekly to monitor project progress. Feedback was submitted online by students, monitors, and supervisors. It is shown that there are positive and significant relationships between feature use and weekly student progress and motivation ratings, and also with their dissertation mark. This suggests that some system features enhanced student self-motivation beliefs, self-observation, and self-reflection. Also, features were ranked as to their impact on student self-regulated learning, and a narrative case study exploring processes behind the effects is provided. High impact features were graphical student progress visualisations, a ranking table, the virtual project page listing past feedback and providing project management tools, and weekly progress feedback. Evidence for between-monitor effects on student dissertation mark as well as system use and successful system support for information exchange is also presented. The contribution of this thesis is novel and noteworthy since it (1) shows the effects of web-based monitoring features on self-regulated learning, (2) shows how features can be used for implementing principles of good practice, and (3) draws on the effect of monitors in the context of this study.

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Declaration of Authorship

I, Till Rebenich, declare that the thesis entitled *Computer Support for Self-Regulated Student Learning in Individual Project-Based Settings* and the work presented in the thesis are both my own, and have been generated by me as the result of my own original research. I confirm that:

- this work was done wholly while in candidature for a research degree at this University;
- none of this work has previously been submitted for a degree or any other qualification at this University or any other institution;
- where I have consulted the published work of others, this is always clearly attributed;
- where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
- I have acknowledged all main sources of help;
- this thesis is based entirely on work done by myself and none of it was done jointly with others;
- none of this work has been published before submission, except as noted in section 1.2 on page 18

5th July 2012

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Finally, I would like to express my gratitude to my parents for their continuous support and understanding. This thesis is dedicated to them.

Chapter 1

Introduction

To achieve great things, two things are needed: a plan, and not quite enough time. (Leonard Bernstein)

The work presented in this thesis examines the use of technology for enhancing students' self-regulated learning in individual project-based learning in a higher education environment. Self-regulated learning is when learners are active participants in their own learning with regard to their metacognitive processes, motivation, and behaviour [Zimmerman, 2011], which is increasingly required from students in higher education. Learning in such contexts is characterised by a high degree of learner autonomy and requires students to take responsibility for their own learning, define goals and tasks, develop and maintain self-motivation, pursue their strategic plan, and adjust it in response to internal and external feedback, which is the result of a monitoring process. In his model of self-regulated learning, Zimmerman [2011] suggests that this process is divided into three distinct phases which are linked in an iterative and cyclic manner, namely (i) forethought, (ii) performance, and (iii) self-reflection phase. Strategic planning and self-motivation beliefs are key aspects of the forethought phase, learners perform learning tasks and monitoring in the performance phase, and adjust their behaviour as a result of the monitoring process in the self-reflection phase.

Against this background, this work focusses on four major learning aspects worth investigating in the context of self-regulated learning, and is aimed at analysing – by means of experimentation and empirical research – how computer technology can support and enhance these aspects. In the remainder of this work, these aspects are referred to as *technology-supported learning aspects* (TSLAs), which will be described in detail in the following paragraphs. They are (i) time management, (ii) motivation, (iii) progress awareness, and (iv) monitoring. These TSLAs directly relate to components in Zimmerman's [2011] model of self-regulated learning. What is more, this work also looks at suitable implementations of some of the seven principles for good practice in undergraduate education presented by Chickering and Gamson [1987], which also directly relate to the four TSLAs. In particular, the focus is on the principles "encouraging student-faculty contact", "emphasising time on task", "providing prompt feedback", and "communicating high expectations".

Motivation Motivation is a central aspect of self-regulated learning in the forethought phase. It can be defined as "energizing or arousing mechanisms" making the student become physically or mentally active [Kleinginna and Kleinginna, 1981]. A learner's self-motivation beliefs are dependent on what outcomes they expect, beliefs about their own capabilities (self-efficacy), their interest in the task, and their orientation towards goals. Student learning can be focussed on the material (learning goal orientation) or the student's achievement in relation to other learners (relative ability goal orientation). In the latter case, their self-motivation beliefs are influenced by the availability of information about their peers' performance [Wolters et al., 1996]. There are mixed results regarding the effect of relative ability goal orientation on students' self-motivation beliefs, but Wolters et al. [1996] found that it positively affects students' interest in the task and their self-efficacy, which in turn positively influence their self-motivation beliefs. Motivation can originate from true interest in the task (intrinsic), that is, when the task itself is perceived valuable and relevant, and external reinforcement (extrinsic) such as reward, deadlines, competition, and so on [Deci et al., 1991]. Moreover, positive and statistically significant relationships of motivation with time management have been found. For example, Francis-Smythe and Robertson [1999] found that motivated students are generally better in planning their work than unmotivated students. Prior research on motivation was conduced mainly in the area of intelligent tutoring systems (ITS) [del Soldato and du Boulay, 1995; de Vincente, 2003], user interfaces with online virtual characters [Kim et al., 2006; Rebolledo-Mendez et al., 2006], and has led to the development of several motivational models [Keller, 1987; Keller and Burkman, 1993].

Time Management Similarly, time management, that is, the control of one's own activity relative to time-related factors [Lewis and Hills, 1999] has been identified as an important "soft skill" for university students. It is an important requirements for successful self-regulated as well as autonomous learning in higher education and a key component of successful student self-regulation when it comes to goal setting, strategic task planning, and continuous control in the task performance phase. Goals lead to a set of tasks which are measurable chunks of work, which make both progress and achievement measurable. Highly self-regulated learners device a structured plan based on short and long-term goals [Zimmerman, 2011] and are generally more self-motivated than poorly self-regulated learners [Schunk and Usher, 2011]. In study advice literature, it is claimed that good time management helps reduce stress and results in more control over both study and leisure time, higher self-confidence, more high-quality output, and increased performance and productivity [Deese and Deese, 1979; Marshall and Rowland, 1998; Rowntree, 1998; Payne and Whittaker, 2000; Drew and Bingham, 2001; Cottrell, 2003; Price and Maier, 2007; Claessens et al., 2007]. Empirical evidence also suggests that time management practices can lead to increased academic performance in students [Macan, 1990; Britton and Tesser, 1991; Trueman and Hartley, 1996]. However, many students still struggle with time management and study planning. Main [1980] describes their main problems as being the inability to keep themselves organised, to plan their work properly, and to meet assignment deadlines. Similar findings are reported in study advice literature, indicating that the relative importance of study time management in higher education as one component among other study skills is widely accepted and acknowledged. At the same time, time management is often regarded as an incidental skill [Smith Terry, 2002], and as such there is very little official institutional support for students who feel that they have deficits, they are simply expected to acquire those skills "on the way". Zimmerman et al. [1994] emphasise that teaching time management should be an integral part of every curriculum. Regarding computer support, time management tools have been around for quite some time, and it has been found that students use individual toolsets consisting of both paper-based and electronic instruments rather than one exclusive tool. However, most standard software tools were designed for use in the professional workplace. In other words, they are aimed at professionals with time management experience and clearly structured working environments, while students may require additional guidance and higher connectedness with their peers, mentors, and teachers, supporting social aspects of learning.

Progress Awareness For developing relative ability goal orientation, encouraging students, and the enhancement of user connectedness in online learning environments, *awareness* is an important catalyser [Dourish and Bellotti, 1992; Mochizuki et al., 2008; Markopoulos, 2009]. According to Dourish and Bellotti [1992], awareness is when students are able to understand what their peers are doing from their interactions with a virtual environment and when this understanding forms the context for their own doing, for example, when a group of students engage in a group learning activity or project. Substantial prior research on awareness has been conducted in the area of distributed group-based projects and collaborative learning. In these contexts, the focus is on enabling community building, group formation, user connectedness, and for generating a cue-rich shared working environment [Schmidt, 2002; Markopoulos, 2009]. From a more technical point of view, awareness can be achieved by (i) capturing user interactions with the system, (ii) visualising them in a suitable way, and (iii) the interpretation of visual cues by system users [Brézillon et al., 2004]. In self-regulated learning, such information can originate from students' self-observation and feedback from external sources (mentors, teachers) and contribute to their self-reflection and self-evaluation; if the information relates to student performance or progress, the term *progress awareness* is used. This, in turn, affects their behaviour towards self-motivation and strategic planning. Closely related to the concept of awareness is that of social presence, which refers to the set of abilities enabling students to engage in "interpersonal interactions" via a medium (here: the virtual environment) [Kehrwald, 2008]. It was used by Eisenstadt and Dzbor [2002] in a synchronous text-based instant messaging context, where physically disconnected users could interact and see other users and resources in their area as well as their availability on a virtual map. They refer to this concept as “enhanced presence”. Bai [2003] hypothesises that enhanced presence positively affects user motivation. Researchers have also looked at data visualisations for learner awareness, both in traditional (see for example Govaerts et al. [2010]) and collaborative project-based settings [Mochizuki et al., 2008]. It was found that these techniques encouraged students to work on their tasks and increased their sense of a learning community as well as user connectedness.

Monitoring In self-regulated learning, students normally apply self-observation techniques when performing learning tasks. These techniques include self-recording and monitoring [Zimmerman, 2011], which is the process generating internal feedback, and are considered important for student self-regulation because they directly affect students' self-reflection on their achievement. Besides self-monitoring, feedback can also originate from external sources (peers, teachers, mentors, and so on). Both types of feedback are generally more effective if preceded by strategic planning generating concrete and measurable performance indicators [Butler and Winne, 1995]. Strategic planning involves the termination of learning tasks and activities with a certain planned outcome. Effective feedback is then generated based on these planning metrics. Carless et al. [2011] emphasise the increasing role of technology for the generation of feedback by virtue of it being more prompt and dialogic in nature. However, empirical research has primarily looked at the effect of feedback on student engagement, which is hypothesised to be positively affected by certain software tools [Hepplestone et al., 2011]. The importance of cognitive feedback for learning has also been emphasised in prior work [Butler and Winne, 1995]. Cognitive feedback goes beyond outcome feedback, which merely indicates whether formal learning task progress requirements have been met by the student. More specifically, cognitive feedback provides additional cues linking achievement with these progress metrics. While its importance is acknowledged, this work did not specifically look at feedback content but at the general effect of monitoring and feedback on student motivation and performance.

1.1 Research Focus

The focus of this work is on the evaluation of software features supporting student self-regulated learning based on the model of Zimmerman [2011] and Chickering and Gamson's [1987] seven principles for good practice in undergraduate education. All research presented here is set in the context of higher education with project-based settings being a primary focus.

A survey on technology use for time management was conducted involving students in the School of Electronics and Computer Science (ECS) at the University of Southampton. The aim was to gain a general understanding of student use of devices (including mobile devices), software applications, and software features for study planning. Then, an experimental research study using an online study planning system prototype was conducted in two first-year undergraduate modules in the school. While this study was unsuccessful due to low student participation, it informed the design of a follow-up research study in the context of Master of Science (MSc) summer projects using an online planning and information system.

This second quasi-experimental research study involved 290 students studying on a Master of Science (MSc) degree in ECS; due to school policy constraints and ethical concerns, a truly experimental study could not be conducted. In the study, an online information system was used for monitoring MSc projects, that is, individual student projects leading towards the final MSc dissertation. In the United Kingdom, these projects take place over the summer at the end of the one calendar year-long MSc programme and are supervised by an academic. Dissertations are marked independently by two to three examiners following a marking scheme, and all summative assessment is independent of information system use.

In the research study, the information system was combined with an educational strategy: a complementary monitoring scheme was implemented whereby postgraduate research students acted as project monitors and met with groups of MSc students once every week to track their progress, provide feedback, and encourage peer support amongst group members. The information system supported this scheme by collecting data on student progress, motivation, and report metrics, and by providing features supporting the four central learning aspects presented above.

Motivation was implemented as a set of tools influencing learners' goal orientation, self-efficacy, and outcome expectancies: a ranking table was provided to enable learners to compare their own MSc project progress to that of their peers, and graphical visualisations such as histograms, line graphs, and bar charts were also used for that purpose. Visualised data originated from weekly progress and event attendance feedback by students themselves, their monitor, and their supervisor. To push certain information to the learner, email notifications were also used. Time management features were a task list for managing project tasks, an online event calendar for meeting organisation etc., a virtual MSc project page containing these two components as well as general project information, and a group page for organising monitoring group meetings. Features such as graphical visualisations (histograms, line graphs, and bar charts), the ranking table, a news feed displayed on the main system page, and email notifications were used to implement progress awareness. Finally, for the purpose of implementing monitoring, online forms for submitting progress as well as event attendance feedback and comments on the virtual group page were provided.

Apart from objective system data, subjective feedback was also collected from students and monitors using online questionnaires and semi-structured informal interviews in monitoring groups. Furthermore, a narrative case study using three example students (A, B, and C) was conduced based on empirical results and self-regulated learning theory, exploring possible concrete effects of system use from the perspective of these students. Three main hypotheses were made in the context of the research study:

1. The use of software features supporting technology-supported learning aspects motivation, time management, progress awareness, and monitoring positively affects students' self-regulated learning in individual project-based settings. More specifically, (i) motivation features positively affect perceived student motivation and transitively their academic achievement (dissertation mark) by enhancing students' self-motivation beliefs, (ii) time management features positively affect student progress and academic achievement by enhancing student self-control and self-observation, (iii) progress awareness features positively affect perceived student motivation and transitively their academic achievement by influencing their goal orientation, and (iv) monitoring features positively affect perceived student progress, motivation, and academic achievement by means of enhancing their self-judgement and reaction to feedback (the outcome of the monitoring process).

2. The use of features for technology-supported learning aspects leads to measurable changes in student perception and behaviour which are explainable by reference to four selected principles for good practice [Chickering and Gamson, 1987]. Measurable changes are (i) perceived feature helpfulness for project management, (ii) perceived motivational effect of features, (iii) weekly student motivation ratings, (iv) weekly student progress ratings, (v) student dissertation mark, (vi) feature use, and (vii) correlations of aforementioned measures. Existing changes in student behaviour and perception demonstrate the importance of such features for self-regulated learning and are used to refine and extend the list of technologies supporting the corresponding principles provided by Chickering and Ehrmann [1996]. In particular, (i) progress reports, event attendance feedback, and group comments enhance student-faculty contact, (ii) project page, task list, and event calendar emphasise time on task, and (iii) progress awareness and monitoring features enable prompt feedback and are suitable for communicating high expectations to students.

3. Monitor feedback and interactions with the system positively affect student motivation, academic achievement, and their system activity, showing that the system was effective in combination with the monitoring scheme and that there is a working feedback cycle between these two user roles.

1.2 Contributions

Based on related work, four technology-supported learning aspects (TSLAs) for student self-regulation in individual project-based contexts were identified and formalised (see above). These aspects are (i) motivation, (ii) time management, (iii) progress awareness, and (iv) monitoring. They are directly related to key components of Zimmerman's [2011] model of self-regulated learning and four of Chickering and Gamson's [1987] seven principles for good practice in undergraduate education (see Figure 1.2.1). A set of web-based system features implementing each of the four TSLAs was used in the MSc project monitoring system over a period of 17 weeks.

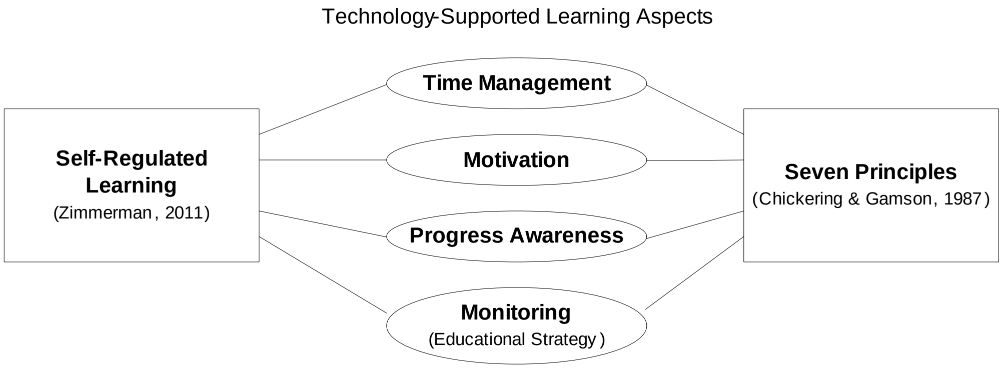


Figure 1.2.1: Technology-supported learning aspects and their relationship to self-regulated learning [Zimmerman, 2011] and the seven principles [Chickering and Gamson, 1987]

The main contributions of this thesis are:

1. Based on the model of Zimmerman [2011], it is established that TSLA features can enhance self-regulated student learning by positively affecting student motivation, progress, and academic achievement. Furthermore, an impact ranking of features relative to each TSLA is provided, taking statistical results, subjective feedback, and usage data into account. Evidence of possible underlying self-regulated learning processes affected by these TSLAs is also provided using a narrative case study.

2. Based on the first contribution, suitable technologies for enhancing four out of the Seven Principles [Chickering and Gamson, 1987] are provided, refining and extending the existing list of implementations provided by Chickering and Ehrmann [1996]. The four selected principles are (i) encouraging student-faculty contact, (ii) provision of prompt feedback, (iii) emphasising time on task, and (iv) communicating high expectations.

3. It is shown that the web-based monitoring system enhanced the efficiency of the monitoring scheme in the usage scenario presented in this research study. In particular, monitor system activity positively affects that of students, some monitors have positive effects on their students' academic performance, and the system enables a feedback cycle between both user roles.

In more detail, evidence in favour of the first research hypothesis was found. There are (1) positive and statistically significant relationships between student use of motivation features and their average weekly self-rated, monitor-rated, and supervisor-rated motivation as well as project progress, and also their dissertation mark, (2) between event calendar use and student as well as supervisor-rated student progress, between task use and supervisor-rated student progress, and between views of the virtual project page and student progress as well as their dissertation mark, although overall event and task use by students was generally low, (3) between use of charts/graphs and student motivation, between student views of the home as well as project page and both their motivation and dissertation mark, and student interactions with the news feed and supervisor as well as monitor-rated student motivation, and (4) between online feedback submissions and student progress, motivation, and dissertation mark, between event feedback submissions and student progress as well as supervisor-rated motivation.

Furthermore, there is also evidence in favour of the second hypothesis. Firstly, regarding the enhancement of student-faculty contact, weekly feedback, charts, and home as well as project page were used frequently by students, their use is positively and significantly related with average student motivation ratings and partially their dissertation mark, and their perceived motivational effect was also rated highly. Hence, their use in software can enhance student-faculty contact. In contrast, direct dialogic communication features such as group comments were not used frequently, and no positive effects on student motivation were found. Secondly, inconclusive evidence exists for features emphasising time on task (event calendar, task list, and project page) since their use by students remained low throughout the study, although their perceived helpfulness for project management was rated highly. Many students also reported that they used external tools for this purpose. Thirdly, the weekly progress report system, the news feed, and visualisations of student progress ratings were found to support the provision of prompt feedback. Fourthly and finally, high expectations were successfully communicated to students using textual comments in progress reports, ratings, and visualisations of student progress, while supervisor feedback was found to be more effective than that of monitors.

Regarding the third hypothesis, evidence exists for some monitors having a positive effect on their students' system activity and academic achievement when compared to other monitors. Furthermore, time-related usage patterns are very similar between students and monitors, and their between-role system use is strongly and significantly related. There are also positive and significant relationships between different kinds of email notification sent in response to online user activity and some student progress and motivation ratings. What is more, it is shown that the primary aim of system, that is, enabling information exchange and a working feedback cycle between monitors and students, was achieved.

To complete the description of contributions, this work also provides a detailed discussion of student self-regulatory processes behind the results obtained from statistical analysis. Results are used to rank the impact of system features on student self-regulated learning in relation to all four technology-supported learning aspects. Finally, a narrative case study exploring concrete effects on student self-regulation is provided using three sample students.

The research presented in this work is original and significant since it (1) shows the effect of web-based monitoring system features on four self-regulated learning aspects, (2) reveals that some features can be successfully used to implement four out of seven principles for good practice in undergraduate education [Chickering and Gamson, 1987], (3) provides evidence for monitors and the monitoring scheme having a positive effect on student behaviour, indicating that their combination was successful, and (4) employs a significant number of participants (378 in total) consisting of students, monitors, and academic staff.

The work in this thesis has contributed in part or full to the following publications:

- Till Rebenich, Andrew M. Gravell, and Thanassis Tiropanis. *Motivating University Students Using a Location-Aware Time Management System with Social Networking Features.* In Proceedings of ED-MEDIA World Conference on Educational Multimedia, Hypermedia and Telecommunications '10, Toronto, Canada, AACE, 3220-3224, 2010
- Till Rebenich, Andrew M. Gravell, and Thanassis Tiropanis. *Survey of Students' Technology Use for Time Management.* In Proceedings of ED-MEDIA World Conference on Educational Multimedia, Hypermedia and Telecommunications '10, Toronto, Canada, AACE, 3134-3141, 2010
- Till Rebenich, Andrew M. Gravell, and Thanassis Tiropanis. *Evaluating a Web-Based Information System for Managing Master of Science Summer Projects.* In Proceedings of ITiCSE Annual Conference on Innovation and Technology in Computer Science Education '11, Darmstadt, Germany, ACM, 2011

1.3 Outline

This chapter has introduced the idea of enhancing student performance and motivation using social presence, progress awareness, and time management techniques in virtual online planning environments.

Chapter 2 provides a comprehensive overview of related work in the area of time and project management, motivation, social presence, awareness, feedback and monitoring, and also introduces the seven principles of good practice in undergraduate education. This should enable the reader to understand the basic concepts behind these topics and the definitions of terms used in this thesis. The chapter is concluded by a summary of insights gained from the literature review and an outline of the four technology-enhanced learning aspects and their relationship with self-regulated learning and the seven principles.

Chapter 3 presents the results of a survey conducted in the school in June 2009. It was used to gain a general understanding of electronic devices, applications, and features used for time management by electronics and computer science students. The results were also used in the design of system prototypes for two research studies conducted in 2009 and 2010.

Chapter 4 provides an overview of the design of a first online study planning system prototype and an experimental research study involving undergraduate first-year students in the computer science discipline. Although this study did not yield a large enough data set for in-depth analysis, it informed the design of a successful follow-up study.

Chapters 5 and 6 present the design of the quasi-experimental research study involving MSc students in the school, the information system used in this study as well as a detailed overview of all relevant results related to the main research hypotheses presented earlier in this chapter, and a comprehensive discussion of these results. Furthermore, a short summary of theoretical background material on statistical tests used in the analysis is given at the end of Chapter 5.

Finally, Chapter 7 outlines the main contributions of this thesis, how they relate to other work, and suggestions for future work based on the study results and subjective feedback obtained from study participants.

Chapter 2

Related Work

This chapter introduces related work on self-regulated learning (section 2.1) and four important learning aspects thereof, namely time and project management, student motivation, awareness and social presence, and progress monitoring. Furthermore, seven principles of good practice in undergraduate education [Chickering and Gamson, 1987] are presented. All topics are covered in the context of learning in higher education environments, and a wide range of sources from psychology, education, and computer science were used.

More specifically, section 2.2 describes different kinds of motivation, the importance of motivation for learning, and ways of detecting student motivation and instigating it by means of software. Social presence and awareness (including progress awareness) are two prominent ways of doing this; they are described in section 2.4. Techniques derived from these two concepts were used in the software systems presented later.

Section 2.3 provides a definition of time management, its use and importance in educational contexts, and how it relates to project management. Furthermore, individual differences in time perception and two examples of time management processes or strategies are described. The section concludes with an overview of existing software supporting student time management. The work summarised in this section is relevant as it helps in understanding the theoretical foundations of these concepts, and was used in the design of prototypes and research studies making up the contribution of this thesis.

Section 2.5 introduces the concept of monitoring and feedback, its importance for self-regulated learning, and outlines why it is still a problematic aspect of student learning. The cognitive processes resulting from feedback are also described.

Section 2.6 gives an overview of Chickering and Gamson's [1987] seven principles for good practice in undergraduate education, aimed at improving teaching and learning in higher education. These principles play an important role when designing software for these environments and also relate to the main self-regulated learning aspects mentioned earlier.

Finally, in section 2.7, a summary and synthesis of all important aspects from literature is provided. More specifically, the relationship between the four main aspects of self-regulated learning and Zimmerman's [2011] model of self-regulated learning as well as Chickering and Gamson's [1987] seven principles of practice are explained. This includes a prediction of possible effects of computer tools on student time management, motivation, and performance.

2.1 Self-Regulated Learning

According to Zimmerman [2011] self-regulated learning is when students are "metacognitively, motivationally, and behaviorally active participants in their own learning processes". In this context, student self-regulation is regarded as an iterative, cyclic process involving four main aspects [Butler and Winne, 1995; Steffens, 2006]: (i) goal setting, (ii) monitoring, (iii) feedback, and (iv) self-evaluation. Self-regulated learning is becoming increasingly important in higher education environments as they are gradually shifting towards more learner-centredness and autonomy and moving away from the idea of traditional instruction. This requires students to be proactive in their learning which no longer "happens to them in reaction to teaching" [Zimmerman, 2002]. Key skills in this process are personal initiative and perseverance.

While a great number of self-regulated learning models exists, Zimmerman [2011] provides a relatively comprehensive and recent model which is depicted in Figure 2.1.1. In this model, motivation is identified as a key driver of student self-regulation. In its absence, students are more likely to procrastinate and fail to achieve good academic performance. Students' motivational feelings are defined as their "personal initiative, perseverance, and adaptive skill" [Zimmerman, 2011] in the learning process. It is further claimed that motivation increases students' attention to the learning process and its outcomes, their choice of task, and their persistence on time-consuming tasks. Motivation can originate from various phases in the model depicted in Figure 2.1.1.

In the *forethought phase*, students normally analyse the given learning task by setting themselves goals and applying strategic planning techniques. Highly self-regulated learners will have a set of short-term and long-term goals and devise a structured plan of how to achieve them, while poorly self-regulated learners will be studying spontaneously and without planning. Secondly, students reflect on task characteristics and develop a self-motivation strategy based on their self-efficacy, expectancies about the task outcome, their valuing of and interest in the task, and their orientation towards goals. Self-efficacy is part of a self-reflection process in which human beings evaluate and change their thinking and behaviour [Pajares, 1996]. It is defined as the "belief in one's capabilities to organize and execute the courses of action required to manage prospective situations" [Pajares, 1996]. In the context of learning, this denotes a learner's belief in their own capabilities to master a learning task. Self-efficacy, in turn, is dependent on the specificity

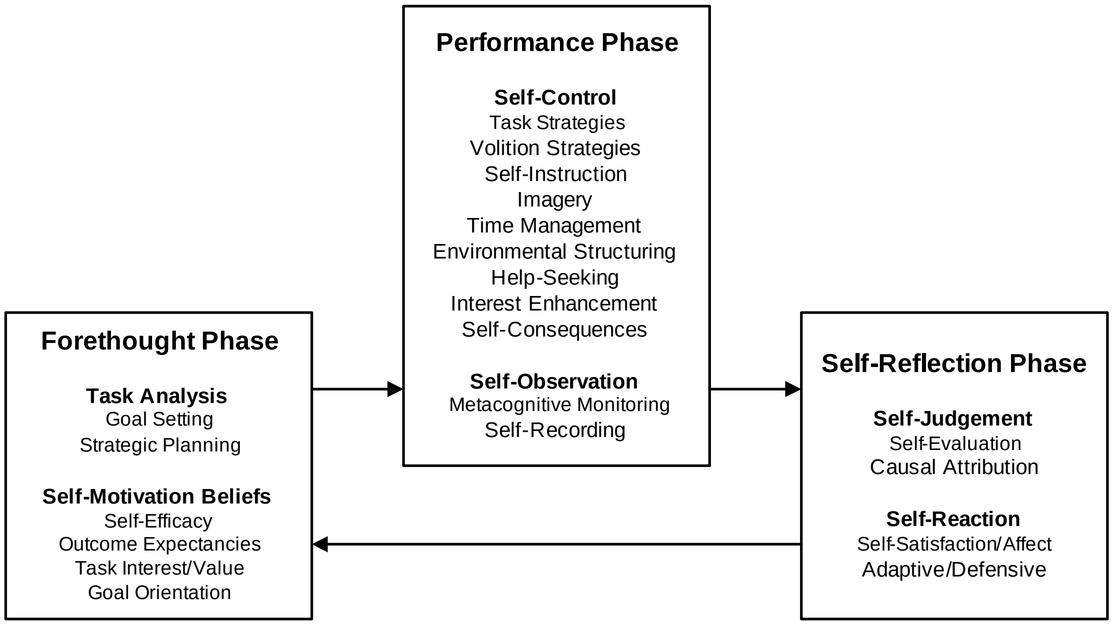


Figure 2.1.1: Self-regulated learning process (adapted from Zimmerman [2011])

of the goal and on the amount of comparative information available about other learners' problem solving abilities [Schunk, 1990] and the information about task progress, affecting the learner's choice of activities (those in which they feel confident), the degree of effort put into performing these activities, the level of persistence, and their achievement [Schunk and Usher, 2011]. Another important aspect of students' self-motivation beliefs is their goal orientation, which is defined as "different ways of approaching, engaging in, and responding to achievement situations" [Pintrich and De Groot, 1990]. There are two types of goal orientation, namely *learning goal orientation* and *relative ability goal orientation* [Pintrich and De Groot, 1990; Wolters et al., 1996]. The former denotes students focussing on learning the material, whereas the latter is when students want to show their ability in relation to other learners. With regard to student motivation beliefs, learning goal orientation is said to be beneficial while relative ability goal orientation is said to have negative effects. Consequently, learning goal orientation is expected to lead to higher student self-efficacy and less anxiety regarding tests. In an empirical study involving 434 junior high school students with an average age of 12.6 taking mathematics, English, and social studies classes, Wolters et al. [1996] found that learning goal orientation correlates positively with adaptive motivational and strategy use results in all subjects. In particular, these are task value, self-efficacy, and cognitive as well as self-regulatory strategy use. However, no relationship was found with student academic performance (grade point average). The study was based on previous work in this area, namely that of Pintrich and De Groot [1990], which reports positive links between students' self-motivation beliefs, their cognitive engagement, and their academic performance in the classroom. In contrast, findings on relative ability goal orientation are conflicting. While some sources report negative effects on self-motivation beliefs, Wolters et al. [1996] also found positive effects on task value, self-efficacy, and cognitive as well as self-regulatory strategy use in all three subject areas.

In the *performance phase*, when students actually perform the learning task, they apply a set of self-control strategies. Poorly self-regulated learners will not apply any strategic approaches. Such strategies are imagination and task strategies helping the student learn, volition to control their actions and to prevent them from pondering on errors, self-consequences such as punishment and reward, structuring of their environment such that it becomes beneficial for task completion, and interest enhancement by converting tasks into challenges. Furthermore, self-regulated learners constantly observe their doing and their performance using metacognitive means and recording techniques for tracking changes and for supporting their time management.

Finally, in the *self-reflection phase*, students evaluate their performance and causal relationships between their actions and the task outcomes. These causal attributions can positively or negatively influence learner motivation. The more students apply strategic planning during the forethought phase, the more likely they are to attribute failure to bad planning. Conversely, students not applying any strategic planning are likely to attribute their failure to low ability. Based on this self-judgement, students then develop some degree of satisfaction affecting the way they change their approach to the task. For example, students with high satisfaction are likely to adapt their approach, while those with low satisfaction will probably attribute their failure to "uncontrollable causes" and react with procrastination, problem avoidance, or even apathy. The outcomes of the self-reflection phase, in turn, influence the learner's actions in the forethought phase of the next iteration. Students' self-reflection is influenced considerably by feedback [Butler and Winne, 1995].

Based on Zimmerman's model (see Figure 2.1.1), four important learning aspects are identified and described in the following sections: (i) student motivation is a key aspect of the forethought phase and described in section 2.2, (ii) time and project management are important for goal setting in the forethought and self-control in the performance phase (see section 2.3), (iii) monitoring enables self-recording in the performance and self-judgement in the self-reflection phase (see section 2.5), and (iv) progress awareness also influences students' self-reflection (see section 2.4).

2.2 Motivation

Kleinginna and Kleinginna [1981], who conducted a review of motivation definitions, suggest the following comprehensive and physiological definition:

> *Motivation refers to those energizing/arousing mechanisms with relatively direct access to the final common motor pathways, which have the potential to facilitate and direct some motor circuits while inhibiting others.* [Kleinginna and Kleinginna, 1981]

However, they also found that underlying physiological and psychological mechanisms are not fully understood. There seems to be an extensive overlap between motivation and learning, motivation and ability, and motivation and emotion. Zimmerman [2011] identifies motivation to be a key facilitator of self-regulated learning; the relationship between these two aspects is one of the main foci of this work. Background information provided here is important for understanding motivational techniques used in Chapters 4 and 5. In self-regulated learning, the learner's motivational beliefs affect their decision to partake in a learning activity, the effort they put into this activity, and their persistence [Wolters et al., 2011]. This must be contrasted from learners' self-regulation of motivation itself, which is the process of "reflecting the thoughts and actions through which students deliberately try to influence their own motivation or motivational processing" [Wolters et al., 2011]. In this process, self-monitoring of motivational state is a crucial factor. For example, students must be conscious of their lack of motivation for them to take action in order to improve this situation.

Both learning and motivation are natural human capacities, but they are also affected by social contexts and the relevancy of the content to the learner. More specifically, such contexts provide the opportunity for them to satisfy their psychological needs (competence, relatedness, and autonomy), enabling motivation in the first place [Deci et al., 1991; Ryan and Deci, 2000]. The importance of autonomy for learner motivation is also emphasised in Dickinson [1995].

The amount and type of information taken in by a learner is dependent on the learner's view of themselves, the learning process, existing goals and expectations, and the interpretation of the task requirements. Feelings like insecurity or anxiety can have a negative effect on or block motivation. Consequently, McCombs [1991] defines a number of features she deems necessary for developing and sustaining motivation: individuals should see education as relevant to their interests, develop a self-esteem which makes them believe that they are capable of reaching learning goals, while also being responsible for defining and achieving them. Moreover, they must develop mechanisms for controlling negative influences on motivation and learning.

2.2.1 Intrinsic and Extrinsic Motivation

Deci et al. [1991] state two types of motivation, namely *intrinsic* and *extrinsic* motivation. Intrinsic motivation is when the activity itself is perceived valuable and self-sustained, meaning that it is caused by oneself [Calder and Staw, 1975], resulting from true interest in the activity [Deci et al., 1991]. This is only possible if the person is led by feelings of competence and self-determination [Deci and Ryan, 1990], that is, in an environment enhancing competence and self-determination intrinsic motivation increases. Conversely, if the environment does not enhance such feelings, intrinsic motivation will decrease. This was also found by Bénabou and Tirole [2003]. In conclusion, a supportive environment with room for learner autonomy, meaning the absence of control, enables self-determination and thus intrinsic motivation [Ryan and Deci, 2000]. More specifically, the social context is characterised by its degree of autonomy support, structure, and involvement [Deci and Ryan, 1990]. Structure refers to expectations with regard to tasks and activities taking place within this context and any feedback provided on these activities, whereas involvement measures the degree of interest others (for example parents, teachers, and so on) have in what we do and their dedication to us. Autonomy was found to be the key catalyser for intrinsic motivation, curiosity, and openness to challenge [Ryan and Deci, 2000]. As a result, learners in less-controlled environments learn more effectively.

Kreps [1997], however, casts doubt on the existence of intrinsic motivation. He argues that what is called intrinsic motivation could in fact be the individual's reaction to "fuzzy" extrinsic motivators. Since these motivators are "fuzzy", one could not observe them and mistakenly assume that they are intrinsic.

Extrinsic motivation is the second type, caused by a specific goal which is independent of the activity itself. The activity is thus reinforced [Calder and Staw, 1975] or controlled [Deci et al., 1991] externally. There are four subtypes [Deci et al., 1991]: *External* extrinsic motivation is the least self-determined form and usually involves an external reward or a threat of punishment. For example, if the behaviour is controlled by feelings of guilt, that is, if the learner has not fully identified with the external regulation and in the absence of a true choice, one refers to it as *introjected* extrinsic motivation. In the next step towards more self-determination, a learner might acknowledge that the externally imposed regulation is important for reaching a particular goal, in other words, the learner has accepted and identified with the regulation. This is called *identified* extrinsic motivation. The most self-determined form is *integrated* extrinsic motivation. It describes the situation where the learner has fully integrated the regulation as it does not conflict with their sense of self. In fact, this form of extrinsic motivation is very similar to intrinsic motivation. However, the former results from personal importance of an activity, the latter from true interest in it.

Both types of motivation interact. Extrinsic motivation can lead towards *internalisation* [Deci and Ryan, 1990; Deci et al., 1991] when the individual realises the importance of initially uninteresting activities for "functioning in the social world". As a result, they become motivated to regulate such activities themselves. This process of *valuing* is enhanced if the learner knows the utility of the activity, has some choice as for the activity and is not pressurised into it, and if their personal feelings towards this activity are acknowledged. The resulting value associated with the activity does not necessarily lead towards intrinsic motivation, but it sparks the individual's willingness to perform it. During internalisation, relatedness is of particular importance. It denotes an individual's feeling to be related to someone or something in their environment. Since an extrinsically motivated activity is not performed out of personal interest, people perform them because they are valued by others they are related with [Ryan and Deci, 2000].

As already stated, the social context affects this process of internalisation and integration. To better understand the interaction between both types of motivation, Bénabou and Tirole [2003] have developed a model with two main actors, namely a principal P and an agent A. P knows the difficulty level b of a task to be performed by A and chooses a policy p (for instance reward, help, surveillance, delegation, disclosure of information) which is an external motivator to A. While A is affected by the policy chosen by P, it may also receive a signal σ from a third party containing private information about difficulty level b. A then selects a course of action e dependent on σ and p as these two determine the attractiveness of the task. By choosing p, P reveals information about their belief in A's ability to perform the task, which can be sensed by A and thus affects their self-confidence and intrinsic motivation. The policy p can be one or a combination of many of the following extrinsic motivators:

Reward

Reward as an extrinsic motivator can be counterproductive [Ryan and Deci, 2000] as it incurs some hidden costs [Bénabou and Tirole, 2003]: it can distract the agent's attention from making progress towards performance, that is, they focus on the task goal (reward) rather than the task itself. Another effect is that such agents tend to choose easier tasks in order to obtain the reward with least effort. Under uncertainty, that is, if the agent is hazy about their ability to perform the task, reward has a negative effect on intrinsic motivation. This is because the agent does not know the true task difficulty level and tries to gain that information from the quantity and quality of the reward offered by the principal. However, reward can be a positively reinforcing factor in the short term, albeit it becomes a negative factor for future motivation. Once offered, the agent expects it to be offered again every time a similar task is to be performed. Also, intrinsic motivation triggered by reward will slump immediately once the reward is discontinued [Deci et al., 1991]. Conversely, if the reward is given spontaneously or ex post, it invariably has a positive effect on the agent's intrinsic motivation.

Performance Feedback, Deadlines, and Competition

Grades, verbal feedback, competition, imposed goals, and deadlines [Amabile et al., 1976] are all forms of control and thus undermine intrinsic motivation [Deci et al., 1991; Ryan and Deci, 2000]. This is on the grounds that the agent feels externally manipulated. However, if people have the choice between tasks to perform, are free to allocate as much time as they want to them, or in cases where they are involved in the decision process (autonomy) intrinsic motivation increases. Surprisingly, this effect also occurs when the principal actively acknowledges an agent's negative feelings about an uninteresting task.

Delegation

A task being delegated to an agent by a principal shows the principal's confidence in the agent's ability to perform it and therefore leads to rising intrinsic motivation. An agent who is both empowered *and* talented is unlikely to damage the principal, as opposed to an empowered *and* untalented agent. Hence, a principal will usually prefer to delegate tasks to talented agents, but they might also consider empowering less-talented agents with the aim of increasing their intrinsic motivation.

Help

It has been found that the more help a principal offers to an agent, the less likely will the agent put a lot of effort into performing the task and their intrinsic motivation will decrease. A permanently high level of help is absolutely detrimental to the agent's intrinsic motivation as it decreases their self-confidence as for their ability to perform the task [Bénabou and Tirole, 2003].

Encouragement

Encouragement is the principal's act of wittingly disclosing information about their assessment of the agent's ability to the agent. This is equivalent to sending out a strong signal σ and enhances the agent's self-confidence and intrinsic motivation [Bénabou and Tirole, 2003].

2.2.2 Effects of Motivation on Learning

The positive and negative effects of intrinsic/extrinsic motivation on learning have been empirically validated. Lepper [1988], for instance, provides a comprehensive overview over these effects on particular variables of learning. The results of his summary are listed in Table 2.2.

There seems to be a consensus that it is favourable to design intrinsically motivating learning tasks and activities since the degree of control and self-determination perceived by the learner is generally higher. The task design should follow four principles [Lepper, 1988]:

Control Extrinsic rewards on intrinsically motivating activities should generally be minimal, while more powerful extrinsic reinforcement is needed initially for less intrinsically motivating activities, gradually decreasing over time. Furthermore, the source of extrinsic constraints should be the task itself rather than an external authority.

Variable	Intrinsically motivated learners	Extrinsically motivated learners
Time on task	Dependent on learner personality and task; more likely to embark on activity if it is deemed interesting	Dependent on probability to achieve extrinsic reinforcer; likely to terminate activity after failure if confidence in own ability is low
Focus of attention	Dependent on own and task goals, and attitude towards exploration; algorithmic tasks: greater performance on incidental task parameters; heuristic tasks: greater performance both on incidental and central task parameters; generally more creative	Dependent on affinity towards extrinsic factors; algorithmic tasks: greater performance on central task parameters
Problem and goal selection	Dependent on interest in task; higher level of detailed processing and comprehension	Dependent on minimal effort necessary to reach extrinsically imposed goals
Mental effort invested in activity	Dependent on own and task goals; choose moderately difficult problems and goals, and are likely to apply exploration and take risk	Dependent on perceived value of goals; choose the way of least resistance
Learning and performance strategies	Dependent on personal value of goal; likely to apply deep approach, and logical performance strategy on complex tasks	Dependent on minimal effort necessary to reach extrinsically imposed goals
Approaching activities	Dependent on intrinsic motivation	Activity is perceived as a "means" to achieve extrinsically imposed goals; will engage in subsequent activities if reward is given; likely to select easier problems and goals in subsequent activities

Table 2.2: Effects of motivation on variables of learning (based on Lepper [1988])

Challenge Activities should provide a continuous level of challenge with goals at medium difficulty level. There should be multiple goals to choose from in order to accommodate a high number of learners.

Curiosity The instructional process should be aimed at unveiling gaps in the learner's knowledge and be related to a domain the learner is interested in.

Contextualisation The activity should be presented in multiple contexts, for example nature, simulations, fantasy, so that the learner realises its practical relevance.

A similar approach to motivation is presented by **?** in their Interest-Driven Learning Design Framework (IDLDF), identifying interest as the most important aspect of motivation in learning. Referring to motivational theory, they describe interest as a natural appeal, yielding the desire to master and demonstrate knowledge, causing persistence, greater effort, and a more strongly connected knowledge. Their framework deals with four context motivators: (i) personally perceived effectiveness is dependent on an adequate level of task difficulty challenging the learner, and a degree of control still allowing for learner autonomy; (ii) learner progress, generated by learners being able to complete tasks and being aware of time and effort already invested in an activity; (iii) the learning environment or social context in which learning takes place, the learner's social role in that environment, membership in groups, and his obligations towards other people; (iv) extrinsic reinforcements such as reward and the prospect of advancement with regard to the social context.

2.2.3 Motivation and the Three Schools of Learning

As already mentioned, the learning environment is a crucial factor of motivation. Environments, in turn, are shaped by supporters of three different schools of learning, namely *behaviourists*, *cognitivists*, and *constructivists*. Behaviourists believe that "learning is a change in observable behaviour caused by external stimuli in environment" [Skinner, 1974]. The learner's mind is seen as a black box, that is, all thought processes leading to a change in behaviour are ignored. Behaviouristic teaching instruments – still used widely in traditional schooling [Brophy, 1998] – are drill and practice based on small portions of learning material, learner assessment, and external feedback. It is noteworthy that their effectiveness for higher-order learning tasks or transfer of learning is still unproven [Mödritscher et al., 2004]. In this first school of learning, behaviour is nearly always extrinsically motivated on the grounds that it originates from control and reinforcement and is invariably based on "carrot-and-stick" approaches [Brophy, 1998]. Due to its "black-box" view on learning, intrinsic motivation is not considered at all [Clark, 2002].

In cognitivism, learning is seen as a process involving memory, thinking, reflection, abstraction, motivation, and meta-cognition [Mödritscher et al., 2004]. The focus is thus on information processing and individual differences in that process. Information received through senses is transferred to either short- or long-term memory after some cognitive processing. The cognitivist school of learning acknowledges the use of learning and cognitive styles when designing the learning environment. As a result, the emphasis is on the student's subjective feelings (for instance needs, goals, thoughts) [Brophy, 1998] and thus their behaviour is primarily intrinsically motivated or caused by integrated extrinsic motivation. The mediation takes place in the learner's cognitions, and the degree of motivation is dependent on (a) the perceived value of the reinforcer, (b) the probability that it is delivered upon successful task completion, (c) the learner's belief in their own capability of completing the task, and (d) the task payoff, that is, whether it is worth spending time and effort on its completion in relation to the personal assessment of the reinforcer value.

Supporters of the constructivistic approach suggest that all knowledge is constructed by the learning experience rather than instruction [Mödritscher et al., 2004]. In the design of learning tasks, they stress the importance of student autonomy and student-centredness [Honebein, 1996]: students are asked to identify their own topics, learning methods, and problem solving strategies in a specified domain, thereby changing the role of the instructor to that of a supporter and consultant in the learning process. Learning activities principally allow for many alternative solutions to a given problem and the learning material still contains "noise" and its complexity is not removed. Students are expected to impose their own structure, filter out such noise, and identify the core problem to be solved. Social interactions, students among themselves and students with teachers, are deemed particularly important, as well as the use of many different modes of content representation. Students are also encouraged to reflect upon their knowledge construction process, that is, how and why a problem was addressed and solved in a chosen way. The high degree of learner autonomy and learner-centredness is a good foundation for intrinsic motivation, provided that there is also a good deal of self-directedness on the learner's part involved. Hence, the lack of extrinsic motivators in constructivist learning environments may eventually lead to the drop-out of less self-directed learners [Mödritscher et al., 2004]. Other sources, for example Lehtinen et al. [1999], argue that the high degree of learner collaboration (group learning) may lead to each group member being an extrinsic motivator to the other members. The reason for this is that intrinsically motivated individual learning goals can only be achieved if the group is successful as a whole. However, this applies only to formal learning and only if external re-enforcers (such as rewards) are delivered to the group rather than to each individual member. In informal learning, especially in adult education [Huang, 2002], interaction is again subject to learner's self-directedness. In such contexts, there exists a natural development towards a more supportive environment for learners: organisational structures have changed from being pyramidal (hierarchical) to networked and uncentralised. Cleveland [2004] refers to this as the "nobody-in-charge" system. This development is driven by increasing organisational complexity, the growing importance of information, and the change of information technology in ever shorter time (every 2–3 years). In such uncentralised systems, the focus is on "personal initiative, voluntary cooperation, joint ventures, [...], and networking", hence more personal autonomy. Therefore, in informal learning, adults need a high level of motivation because they have responsibilities for both work and their families [Lieb, 1991], and can only develop and sustain motivation when new knowledge is suitable for solving real-life problems of the learner [Knowles et al., 2005].

In recent years, a clear shift away from the behaviouristic school towards cognitivism and constructivism has been taking place [Clark, 2002].

2.2.4 Applications

Although there are some applications of motivational techniques in the e-learning domain, the validation of their effectiveness is difficult to establish [Keller and Suzuki, 2004]. In particular, human motivation is complex, there exists a great number of motivational models and theories, and it has proven difficult to use these concepts to guide the design of motivational e-learning systems. Generally, most e-learning platforms still focus too much on the delivery of learning (behaviourism) without considering cognitive learner characteristics and motivation; in other words, they see e-learning merely as another method of delivery [Clark, 2002]. In some cases, applied motivational techniques have even had demotivating effects on the learner because they caused them to have negative feelings such as anxiety, frustration, embarrassment, fear, and shame [Blanchard and Frasson, 2004].

The motivational issues to be addressed by computer-aided learning have been nicely summarised by Lepper and Chabay [1985]: firstly, motivation must be seen in the context of cognitive factors of learning. The questions arising are when to provide help, how much, and how often, but also questions about the kind and time of feedback, pace of teaching, and assessment. Secondly, personalisation of instruction and material plays an equally important role. This also involves a system's reaction to failure and measuring how effective sequences of learning tasks are. And thirdly the application of technology should be context-related, that is, based on the learning task, learning style, and the current stage of the learning process.

The following sections shed some light on motivational models and techniques in e-learning, the way in which they were implemented, and their evaluation. These aspects are typically used in connection with the following terms (see [Paulsen, 2002] for a detailed outline):

E-Learning E-Learning refers to interactive learning with the content being delivered online or in another electronic way and interaction taking place between learner and teacher, or learner and system. The term is also used more generically for all kinds of online learning.

Learning Management System (LMS). A software used for the administration of learning events, providing services such as user enrolment, management of syllabuses, user data collection, reporting and so forth.

Learning Object Elementary container for learning material used e-learning applications. Such objects are designed to be re-usable and can thus be reassembled to form new online courses. Learning objects are described by using a set of meta-data classifiers.

Virtual Learning Environment (VLE). The term VLE is sometimes used synonymously with LMS, however, the former is less focussed on the administration and management of learning. Intelligent Learning Environment (ILE) is another related term falling into this category, emphasising the adaptive character of the learning environment.

Intelligent Tutoring System (ITS). The term is increasingly used to describe any computer-supported learning system containing some intelligence. The more traditional definition, however, refers to a system consisting of four components: domain model, student model, teaching model, and user interface. The domain model contains domain-dependent knowledge, the student model consists of learner characteristics, collected in the course of instruction or defined at the outset, and the teaching model deals with instructional aspects which are then presented to the user through the user interface [Freedman, 2000].

2.2.4.1 Motivational Models and Their Applications

Many e-learning applications make use of motivational design models, most of which are based on psychological aspects of learner motivation. Hodges [2004] points out that albeit such models can provide general motivational principles for the design of instruction, they must not be seen as a "cookbook" telling educators how to motivate the learner. Bong [1996] criticises the abundance of models and raises the issue that there is no comprehensive model incorporating all variables relevant to learner motivation.

One of these models, introduced by Keller [1983] and used in many e-learning systems, proposes four factors influencing learner motivation: interest, relevance, expectancy, and satisfaction. *Interest* refers to the the extent to which the learner's curiosity is aroused and sustained over time, *relevance* denotes the degree of fulfilment of personal learner needs, *expectancy* is the self-assessment of the probability of success, and *satisfaction* the combination of extrinsic and intrinsic motivation in the learner. To achieve interest, it is first necessary to catch the *attention* of the learner and engage them in a learning activity. The model was thus later revised [Keller, 1987] and called *ARCS*, an acronym which stands for the four categories attention, relevance, confidence, and satisfaction, which are equivalent to the four factors mentioned in [Keller, 1983].

Learner attention can be achieved by using techniques such as varying content format and delivery, humour, learner participation, and content contradicting the learner's intuition [Hodges, 2004]. Taran [2005] extended these suggestions by providing 10 concrete motivational techniques for catching learner attention which are based on experience:

1. Use of mandating stimuli, that is, statements which are very likely to trigger a desirable learner behaviour, such as "it is important to realise..." or "remember that..."
2. Using words and phrases triggering learner anticipation, for instance "new", "now", "looking forward to"
3. Designing messages so that they contain incongruous information, in other words, presenting information the learner does not expect
4. Presenting concrete information such as statistics, quotes, and so forth.
5. Utilising a variety of frequently changing material presentation techniques: tone, movement (animation), format, interaction, sensory channel (visual/auditory), information validity
6. Humour as a means of enhancing motivational state
7. Questions to test knowledge/understanding or provocative enquiries
8. Enabling learner participation by providing interactive, simulative, and practical learning activities
9. Breaks every 30 minutes
10. Using storytelling techniques; the story should be as realistic and content-relevant as possible

The second and most important motivational aspect according to Hodges [2004], relevance, can be attained by providing a set of different methods for achieving the learning goal from which the learner can choose. It can also help to clearly state how the learning content is related to the learner now and in the future. Learner confidence is increased by giving a detailed outline of the intended learning outcomes, structuring material so that it is presented to the learner with increasing difficulty, realistic goals, and independent learning strategies. Finally, extrinsic reinforcement such as reward, feedback, and preventing negative learner experiences will lead to learner satisfaction [Hodges, 2004].

To aid instructional designers to instigate and sustain learner motivation, Keller and Suzuki [2004] propose the use of a systematic design approach comprising ten basic steps listed in Table 2.3. The process explicitly contains revision points, taking learner feedback on motivation as a foundation for continuous adaptation of the instructional process. The model was originally meant to be used by instructors to design their courses, however, due to its algorithmic character, it can easily be applied in computer-enhanced learning. However, each step of the design process would have to be extended by material-related information (hardware/software requirements), supplemental material information (for instance textbooks, additional software), and learner support system aspects [Park et al., 2007].

As the 10-step approach turned out to be too time-consuming and complex, a condensed version consisting of a simple matrix was created. Later, Keller and Burkman [1993] added tables and checklists of possible motivational tactics. The simplified version was then implemented by del Soldato [1994] and del Soldato and du Boulay [1995] in an Intelligent Tutoring System (ITS) adapting to the learner's current motivational state. For this purpose, two components were added to the typical ITS architecture, the *motivational state modeller* and the *motivational planner*. The latter acts rule-based on the domain-independent objects *problem*, *help*, *assessment*, *answer*, and so on, whereby the rules are derived from Keller and Burkman's set of motivational tactics. The motivational state modeller detects the learner's current motivational state through their interactions with the system, and the motivational planner then uses a two-step process to adapt the system reaction to this state: in the content planning step, the system determines what material to present next, and in the delivery planning step the way of instruction is chosen.

The detection of motivational state is a non-trivial process based on four different inputs. Initially, the learner fills in a questionnaire assessing their self-confidence, affinity with challenge, and domain-related motivation. This state, however, is likely to change in the course of instruction. Hence, the system utilises continuous communication with the learner so that they can provide feedback about their confidence in the current learning task. Furthermore, the application analyses learner help requests and task completion, which yields the third input. And finally the learner can submit regular self-evaluations of their current motivational state through the interface.

The system has to reconcile domain-related and motivation-related aspects in order to react appropriately, that is, there may be conflicts between the instructional plan, based on the problem domain, and the advice given by the motivational planner. In this context, del Soldato and du Boulay [1995] point out that the limitations of interface devices made it impossible to implement all motivational tactics proposed in literature (see for instance [Keller and Burkman, 1993]).

The issue of motivation detection or "diagnosis" in e-learning was taken further by Vicente and Pain [1998], refined [de Vicente and Pain, 1999; Vicente and Pain, 2000; de Vicente and Pain, 2002], and finally led to a comprehensive work [de Vincente, 2003] outlining the technical requirements for affective intelligent tutoring, specifically in terms of motivational learner modelling and motivation detection. As found by de Vincente [2003], most systems use learner models consisting only of cognitive factors and he suggests that they should be extended by motivational factors. Also, he points out that the use of questionnaires and self-reports as presented in del Soldato and du Boulay [1995] is likely to produce too inaccurate results and is highly dependent on the learner's perception of their own motivational state. Instead, motivational factors should be detectable without inference and directly linked to tutorial actions. He further distinguishes permanent motivational characteristics, called *traits*, which are unlikely to change over time, and transient motivational characteristics, called *states*, likely to change in the course of the

Step	Action	Result/Details
1	Obtain course information	Course description and rationale Setting and delivery system Instructor information
2	Obtain audience information	Entry skills level Attitudes towards school/work Attitudes towards course
3	Analyse audience	Motivational profile Root causes Modifiable influences
4	Analyse existing materials	Positive features Deficiencies and problems Related issues
5	List objectives and assessments	Motivational design goals Learner Behaviours Confirmation methods
6	List potential tactics	Brainstorm lists of tactics Beginning, during, and end Throughout
7	Select and design tactics	Integrated tactics Enhancement tactics Sustaining tactics
8	Integrate with instruction	Combine designs Points of inclusion Revisions to be made
9	Select and develop materials	Select available materials Modify to the situation Develop new materials
10	Evaluate and revise	Obtain student reactions Determine satisfaction level Revise if necessary

Table 2.3: ARCS motivational design process [Keller and Suzuki, 2004]

interaction with the system. This leads towards a new motivational model, containing aspects of Keller's model and other broad categories, partly derived from other models, which is depicted in Figure 2.2.1.

For the detection of these motivational factors, de Vincente [2003] uses a questionnaire, learner self-reports in the course of instruction, affective language in human-computer interaction, and a set of motivation diagnosis rules. In contrast to del Soldato and du Boulay [1995], these rules are not based on motivational theory but inferred from an empirical study in which students had to predict the likely motivational state of other students based on a replay of their previous interactions with the tutoring system [de Vicente and Pain, 2002]. He argues that most aspects of theoretical models are either not applicable to e-learning or too generic. Surprisingly, the results of a field study suggest that the acceptance of both the questionnaire and the self-report is quite

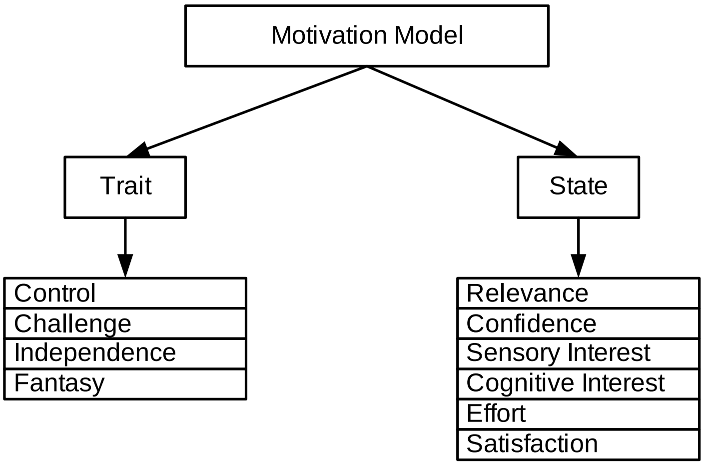


Figure 2.2.1: Motivational model used by de Vincente [2003]

high and only decreases when learners use the system for a longer time.

While the former approaches are aimed at using the learner's motivational state for dynamic and automatic system adaptation, other approaches such as that proposed by Hsu et al. [2006] use Keller's ARCS model to visualise learner motivation. The resulting scenario map can then be used by teachers to manually adapt their instruction.

2.2.4.2 Motivation in Constructivist E-Learning Applications

In the constructivist school of learning, the emphasis is on learner participation in the learning process, autonomy, and social interaction (see section 2.2.3). The latter is often associated with collaborative or group learning – both terms are used synonymously here. However, the distinction between collaborative and cooperative learning is noteworthy: Collaborative learning refers to all group members jointly and coordinately engaging in finding a solution to a given problem, while in cooperative learning, members assign each other portions of work to be done in isolation and merged into the overall solution to a given problem later [Lehtinen et al., 1999].

Computers are already widely used to support and facilitate collaborative work, primarily in professional work contexts. Such applications are commonly known as "groupware" with Lotus Notes and ICL's Teamware being prominent examples. They enable participants to share, structure and organise information, communicate with each other, schedule events and appointments in personal and public calendars, and provide discussion boards and document storage tools [Lehtinen et al., 1999]. Many of these groupware applications are already widely used in educational environments.

Focussing on the e-learning context, Lehtinen et al. [1999] give a comprehensive overview over tools which have been successfully used for collaborative learning. They stress that most of them are valuable only because they enable learner collaboration in the first place, irrespective of their specific technical abilities. Tools developed for single-user use, for instance, can also be used to build up a collaborative learning environment. Likewise, there are many tools specifically addressing collaborative issues such as brainstorming, annotations, categorisation of ideas, ranking, rating, scoring, and voting by providing suitable interfaces enabling these interactions. Collaborative learning tools can also be categorised by their scope. While some of them only operate inside a particular institution (LAN-based), others enable worldwide collaboration over the internet. Many of them are quite comprehensive, providing multimedia tools, teleconferencing applications, electronic notebooks, hypertext systems, and Wikis (for a full list of applications see [Lehtinen et al., 1999]). Referring to several studies evaluating the effects of collaborative learning tools on achievement and motivation, Lehtinen et al. [1999] state that they were found to have a positive effect on both aspects and could thus be used for improving the quality of learning.

For social interaction to take place, Eisenstadt and Dzbor [2002] propose the use of enhanced presence technologies (see section 2.4 for details). These try to reconcile traditional instant messaging technologies with enhanced ways to manage and visualise social presence in a network of people. More specifically, an instant messaging prototype called "BuddySpace" was created, enabling users to expose their geographical location in an office, on campus, or on a world map, as well as their availability on the time line. Furthermore, the status and location of devices and documents used for collaboration is shown. This functionality is coupled with traditional instant messaging features. The application was successfully used in field trials at UK's Open University, as a "desktop radar" in a distributed scientific collaboration project, and in multiplayer games. Eisenstadt et al. [2003] claim that such technology can enhance collaborative learning by enabling "opportunistic (unplanned) interactions" between participants and finding the "right source of key knowledge". Apart from such ad-hoc interactions, the technology can lead to dynamic, emergent group formation and contextual interaction [Vogiazou et al., 2003]. BuddySpace leaves complete control to the user; in other words, permission for exposing locational data and availability must be explicitly granted. State changes are pushed to all connected users by using the platform-independent Jabber protocol. Bai [2003] suggest that it can be assumed that enhanced presence as a facilitator of social interaction between learners in the domain of online learning is likely to positively influence student motivation. It is argued that this is because of learners feeling less isolated and detached as a result of enhanced participation. This claim has been backed up by empirical evidence in recent years. For example, Rogers and Lea [2005] found a positive correlation between social presence and user motivation to participate in distributed group work, and Tao [2009] also reported a positive relationship between social online presence with student motivation, although more research with larger sample sizes and in different settings was advised. Also, the emergence of more affordable and sophisticated mobile devices such as PDAs and Smartphones could further boost the uptake of social presence technologies in mobile e-learning applications [Park et al., 2007].

2.2.4.3 Other Motivational Techniques

Based on motivational theory covered extensively in section 2.2 and specifically with regard to the implementation of motivational techniques in e-learning, four elementary prerequisites for intrinsic motivation have been identified [Vogel et al., 2007]:

Challenge Challenging learning activities are intrinsically motivating. Challenge, itself sparked by the learner's feeling of self-efficacy, is dependent on the task's difficulty level.

Curiosity Learning activities which are new to the learner and have a medium complexity level bring about curiosity, stimulating intrinsic motivation.

Engagement If a learning activity is interesting and relevant to the learner, they are more likely to engage in it. Engagement is also dependent on learner autonomy, achieved by allowing them to chose between a set of learning tasks.

Control Learners who have the feeling of control over their learning are self-determined. Self-Determination is an important prerequisite for intrinsic motivation.

In their study, Vogel et al. [2007] examined the effect of 6 different e-learning tools on these four elementary prerequisites for intrinsic motivation. The tools used were video lectures, face-to-face tutorials, online tutorials, online discussion boards, individual projects, and examination. The results showed that challenge is promoted by individual projects, examinations, and face-to-face tutorials, control by video lectures and online tutorials, and engagement by online discussion boards and collaboration in online tutorials. However, curiosity was not particularly influenced by any of the tools.

The empirical study of Kim et al. [2006] evaluates the motivating effect of social interaction in human-computer interfaces. More specifically, it focusses on learner self-efficacy which is believed to be critical to task engagement, effort on task, and successful task achievement. This is grounded on previous studies which found a significant relationship between emotional expressions of teachers and peers in a classroom environment and the learner's own emotions and motivation. In order to evaluate whether the same effect can be achieved through e-learning, Kim et al. [2006] used a virtual peer (an animated digital character) simulating a human peer in a task-based e-learning system. The study consisting of three independent experiments found that the competence of the virtual peer (VP) had a significant effect on self-efficacy: learners working with a highly competent VP showed lower self-efficacy with regard to the task than learners working with a low-competent VP. Similarly, VP gender was related to task interest with the male VP triggering higher task interest than the female one. More specifically, interest was higher when the male VP used positive emotional expressions. In the third experiment, the learner was able to interact with the virtual peer by clicking emoticons expressing their current emotional state. The virtual peer would then either respond or not. In the first case, if the VP responds, high learner self-efficacy was detected, while the non-responsive VP had a negative effect on self-efficacy.

A similar approach was taken by Rebolledo-Mendez et al. [2006], who also used an on-screen character for modelling the motivational learner traits effort, confidence, and independence in an Intelligent Tutoring System (ITS). Effort refers to the qualitative and quantitative analysis of the user's interactions with the system and their degree of persistence in case of errors, the confidence level correlates with the degree of challenge sought by the learner, and independence is measured by analysing the degree of help provided by the system during the instruction. In contrast to the virtual peer approach presented in [Kim et al., 2006], the on-screen character used spoken feedback and gestures at the beginning and the end of a learning activity, adapted to the learner's current motivational state. The feedback was generally aimed at encouraging the learner. The model evaluation using a sample size of 19 revealed that the system was able to increase the motivation of those learners whose motivational state was low at the beginning of the instruction. However, initially highly motivated learners achieved lower learning gains (scores) after instruction. Amongst these learners, learning gains were higher for those who actively sought for challenge. These results suggest that initially highly motivated learners do not benefit from motivational techniques while initially low-motivated learners do.

The largely positive effects of on-screen characters, also referred to as pedagogical agents, on interest and motivation were re-stated by Park et al. [2007].

Code et al. [2006] elaborate on the relationship between self-regulated learning and motivation, suggesting that motivation is related to the learner's goal orientation and goal achievement. Learners applying a task-goal or learning-goal orientation use the surface approach to learning and are unlikely to develop task enjoyment and thus intrinsic motivation. Conversely, if a mastery-goal orientation is used, learners apply a deep approach to learning, develop task enjoyment, and are likely to maintain a high level of intrinsic motivation. Taking this relationship and a goal hierarchy defined in [Carver and Scheier, 2004] as a foundation, Code et al. [2006] developed a Goal Setting Kit (GSK), allowing the learner to define learning goals and associate them with specific plans of action. The tool also allows the user to link goals with concept maps, the prioritisation of goals, and provides conflict resolving strategies. Also, plans of actions associated with goals can be scheduled in a personal calendar.

Koike et al. [2005] claim that they are able to increase students' academic motivation in large classes by using an e-learning framework combining several tools such as in-class test programs with automatic marking, online communication and feedback applications, and integrative content management systems. The in-class test program was used to detect the learner's current learning state, enabling instructors to react upon it. The scope of this framework, however, seems to be limited to certain types of class.

2.3 Time Management

Time management is a fairly abstract term referring to the "control [...] of activity in relation to various time-related factors" [Lewis and Hills, 1999]. These factors can be a person's natural rhythm of life, deadlines, or simply the fact that time is passing continuously. The term is misleading: not time itself is managed because its passage cannot be influenced [Lewis and Hills, 1999; Claessens et al., 2007, p. 19]. Instead, we manage ourselves: we can do things faster or not at all dependent on their importance and urgency, or we can make use of other resources (for instance, people working on the same team) in order to perform many activities in parallel, or we use time more effectively, that is, by producing higher quality or quantity output in the same time. While "self management" seems to be the more appropriate term [Lewis and Hills, 1999], it is not specific enough on the grounds that it refers to a whole range of different skills, not exclusively to the use of time. Therefore, throughout this work, the term "time management" is used to refer to self management with regard to time, and the above definition found in the work of Lewis and Hills [1999] is followed. It should be noted, however, that a great number of definitions exist, each of them referring to the particular context it is being used in. A good overview on these definitions is provided by Claessens et al. [2007].

2.3.1 Time Management in Educational Contexts

Interestingly, time management is mostly mentioned in the context of economics and management, and often in connection with phrases like "time is money" [Adair, 1982]. Getting more things done in the same time is associated with higher productivity, and thus higher profit. Consequently, a great number of books can be found on effective time management in organisations.

In contrast, this work is concerned with time management in the context of learning and education. In contemporary study advice literature, one can find the following key issues:

- Apart from timetabled activities such as lectures, there are other learning activities outside the formal teaching timetable [Payne and Whittaker, 2000]. These must be organised and managed in the same manner as timetabled activities, but it is the learner's responsibility.

- The adoption of good time management practices is an essential soft skill. Its benefits are increased employability [Payne and Whittaker, 2000; Cottrell, 2003], less stress, less feelings of guilt, higher self-confidence [Payne and Whittaker, 2000], and more control over study and leisure time [Payne and Whittaker, 2000; Cottrell, 2003; Saunders, 1994]. Drew and Bingham [2001] also claim that it results in

> more and higher quality output. This, in turn, is claimed to lead to increased productivity and performance.

Some of the above claims are supported by empirical evidence. For example, Britton and Tesser [1991] evaluated whether time management skills have an impact on academic grades. Their experiment involved 90 psychology students filling in a 35-item questionnaire. For each question, answers could be chosen from a 5-point Likert scale. The questionnaire comprises 3 sections: the first assesses short-range planning skills, the second time attitudes, and the third long-range planning skills. The time attitudes section evaluates to what degree the student feels in control of their time. The results of their survey were used in correlation analysis together with the grade points achieved by each student. Furthermore, students' aptitude was tested using the Scholastic Aptitude Test (SAT), and the results were then compared to the grade point average. It was found that the components "time attitude" and "short-range planning" correlated positively and significantly ($p < 0.001$ and $p < 0.02$, respectively) with academic performance, (grade point average) while long-range planning did not make a significant difference ($p > 0.05$). The SAT score correlated negatively with long-range planning ($r = -0.28$, $p < 0.05$). The feeling of control over time, which is a result from a positive attitude towards time, also resulted in students being more efficacious as for cognitive processing and behaviour perseverance.

Similar results were reported by Macan [1990]. She tested the relationship between time management behaviour and stress as well as academic performance by using a time management behaviour scale (TMB). Her questionnaire consists of 46 items and was completed by 165 participants enrolled on an undergraduate MBA course and a teaching summer school course. Each item corresponds to a particular time management behaviour and could be answered using a 5-point Likert scale. Furthermore, items were grouped into four factors, namely setting goals and priorities (1), mechanics/planning (2), perceived control over time (3), and preference for disorganisation (4). Apart from using participants' grade points, they were also asked to assess their own performance, somatic tension, and life satisfaction. Participants who were in full-time employment also provided an assessment of their job satisfaction. The TMB score correlated positively and significantly with the self-assessed performance rating, the grade point average, and job and life satisfaction. A negative correlation was found between TMB score and somatic tension. A later study [Macan, 1994] conducted in an organisational context and involving 353 participants in two different companies found similar results. The same time management factors as in their earlier study [Macan, 1990] were used. Again, participants who set goals and priorities and reported a preference for organisation also perceived greater control over time. Greater control over time was in turn positively related to higher job satisfaction and reduced stress. Another objective of this later study was to evaluate whether time management training had a positive effect on adopted time management behaviours. The results suggest that there is no significant effect; in other words, those who received time management training did not report more time management behaviours compared to those who did not receive training.

Trueman and Hartley [1996], on the other hand, only found a modest correlation between academic performance and short-term time management, while the correlation between long-term time management and academic grades was stronger. They also tested the differences regarding time management between mature students and freshmen and found that the former group of students was generally better than the latter group.

In their review of time management literature, Claessens et al. [2007] included 32 empirical studies conducted between the years 1982 and 2004. They found positive relationships of time management with perceived control over time, job satisfaction, and health, while stress was found to be reduced. These findings partly support the claims made in study advice literature above.

Study advice literature also provides some guidelines on activities characterising good time management. Cottrell [2003], for example, suggests that students should first reflect on their current time management. This includes the evaluation of how much time is spent on different types of study activity. Drew and Bingham [2001] as well as Payne and Whittaker [2000] suggest the use of a diary or time log for this purpose. Then, in the second step, a list of targets and tasks should be compiled. Each task should be split into sub-tasks, that is, smaller chunks of work [Cottrell, 2003; Drew and Bingham, 2001]. A list item should be integrated (relating to the larger plan, project, or subject), manageable and realistic, specific (containing a detailed description of the expected outcomes), measurable, and flexible (allowing for unexpected circumstances) [Cottrell, 2003]. For each item on the list, the priority, time to target, resources needed for its completion, the start time, and the deadline should be specified. When doing this, time for unforeseen events such as equipment breakdown, unavailability of necessary resources, sickness, accidents, and others, is to be considered. Furthermore, one should concentrate on "high-payoff activities" and listen to one's body clock [Payne and Whittaker, 2000], that is, perform tasks at peak energy times. Cottrell [2003] also suggests that relaxation and leisure time should be scheduled in the same way. Tasks and activities can be categorised using symbols or colour codes. Finally, the compiled work plan should be monitored and revised regularly [Drew and Bingham, 2001].

In this context, the time to target is often the result of estimation based on past experience with similar tasks. The accuracy of such estimations is dependent on the user's self-assessed time management skills [Francis-Smythe and Robertson, 1999]. People who deem themselves good time managers tend to make more accurate estimations than people reporting poor time management. Those people often over- or underestimate to a considerable extent. They also found that motivation is a crucial factor: more motivated people were better in planning than unmotivated people.

Regarding prioritisation, the task priority P can be defined as a combination of urgency $U = \{0, 1\}$ and importance $I = \{0, 1\}$ [Adair, 1982]. Consequently, P is given as a matrix

$P \times U$, such that

$$P = \begin{pmatrix} U \wedge I & U \wedge \neg I \\ \neg U \wedge I & \neg U \wedge \neg I \end{pmatrix}$$

Covey et al. [1994] refer to item p_{22} in the above matrix P as the forth quadrant. They argue that activities which are both unimportant and not urgent are typically used for time wasting or procrastination, and thus for avoiding work on tasks with priorities in the other three quadrants.

The implementation of the above guidelines characterises students with good time management behaviour. However, there is evidence that this poses a challenge to many students. In his book, Main [1980] provides a summary of the most common study problems in tertiary education and found that these were firstly the inability to organise and plan work properly, secondly meeting assignment deadlines, and thirdly structuring learning material. He states that the most common "complaint of students of all ages, levels of study and disciplines, is difficulty in organising and timetabling their work" [Main, 1980]. By "work" he refers to independent study outside the formal class timetable. Very often, students fail to schedule enough time for these activities as they see study time as that spent in formal classes (lectures and others). What is more, the use of e-learning applications in higher education is increasing. There seems to be evidence that these applications require students to change their approach to time management [Sharpe and Benfield, 2005]. In particular, students often find that they have to adapt their study patterns to the requirements of e-learning software, for example, in terms of the time required for system logons and contributions in on-line learning activities.

Finally, there is evidence that learner personality aspects influence time management. Williams et al. [1995], for instance, found a significant positive correlation between the judgement-perception dimension of the Myers Briggs Type Indicator [Briggs-Myers and Myers, 1995] and short-range as well as long-range planning, and time attitudes as used in Britton and Tesser [1991]. Learners scoring high in this dimension have a preference for steadiness and order, and aim for task completion.

2.3.2 Time-Related Individual Differences

Besides cognitive dimensions, our personality is made up by temporal or time-related aspects. Hall [1983] introduced the terms *mono- and polychronicity*, referring to how many tasks an individual performs at the same time. Hall also uses the terms M-time and P-time to denote mono- and polychronicity, respectively. Both patterns are distinct and usually do not mix in the same context, that is, it can lead to difficulties if monochronic people have to work together with polychrons and vice versa [Hall, 1983; Kaufman-Scarborough and Lindquist, 1999].

Monochronic people do one thing at a time and schedule events as separate items. Their focus is on time-management, tasks, schedules, and procedures, and everything succumbs to that schedule. Very often, these people regard time as an "economical resource" [Lindquist and Kaufman-Scarborough, 2007]. This view leads towards *compartmentalisation*, that is, available time is divided into slots which are occupied by only one task, greatly reducing the context, so that it is often difficult for monochronic people to see how what they do fits into the "larger system" [Hall, 1983]. Also, interaction takes place among no more than two to four people at a time. In order to determine how much time is allotted to a task, M-time systems use prioritisation as a classification system, in other words, high-priority tasks are allotted more time than low-priority tasks.

Polychronic people, in contrast, do many things at the same time and are thus involved in several things at once. The focus is on people involvement and the completion of transactions, while schedules and appointments are regarded secondary, taken less seriously, or even broken. Consequently, appointment times are often vague, for example, "in two days" or "before one hour". Therefore, interaction with many different people and a good knowledge of them are crucial success factors in P-time systems. Polychronic people also see how what they do relates to the whole, however, they may struggle when dealing with new or different tasks.

Interestingly, Hall [1983] observed that monochronic systems are prevalent in North European societies and polychronic systems in the Mediterranean. However, he suggests that most high technology cultures have incorporated both time use patterns. The Japanese, for instance, apply the polychronic pattern when working towards themselves, but are monochronic when dealing with the outside world. Also, females are more likely to be polychronic as they focus on relationships and interactions with other people, and males tend to be monochronic by virtue of them being task-oriented. Conversely, in his quantitative study involving 683 individuals which looked at time-related individual differences, measured against a model comprising 15 dimensions as shown in Table 2.4, Robertson [1999] could not find such a correlation between gender and polychronicity.

Robertson's model already contains aspects of the FAST model devised by Settle et al. [1981]. The latter source focusses on objective and subjective aspects of time. Objective aspects are those which are concrete and measurable, whereas subjective aspects refer to an individual's perception of available time with regard to the task they have to perform. FAST is an acronym for the four dimensions (i) focus, (ii) activity, (iii) structure, and (iv) tenacity. Mono- and polychronicity only cover the structural aspect of time with polychrons disliking structure and monochrons seeing time as divided into even slots into which activities are fit [Kaufman-Scarborough and Lindquist, 1999].

Based on Hall [1983], Lindquist and Kaufman-Scarborough [2007] state that there is an individual preference towards either monochronic or polychronic behaviour. On this basis, they developed the Polychronic-Monochronic Tendency Model consisting of a corresponding measurement scale (PMTS) denoting an individual's tendency towards either

Dimension	**Description** (what is measured?)
Time orientation	Individual's preference for focussing on the past, present or future
Time span	Ability to perform tasks with different time spans
Scheduling	Meeting deadlines and keeping schedules
Punctuality	Being punctual and tolerating unpunctual people
Time boundaries	Clear distinction between work and leisure time
Synchronisation	Synchronising the completion of parallel tasks with others
Coordination	Synchronising the completion of sequential tasks with others
Time buffers	Scheduling time to be used when unforeseen events occur
Pace	Task demands, deadlines
Time urgency	Individual pace
Speed vs. accuracy	Payoff between task speed and task result accuracy
Polychronicity	Doing several things at a time
Awareness of time use	Experience in time use in relation to task progress
Awareness of clock time	Being aware of the actual time
Autonomy	Individual's feeling of control over time

Table 2.4: Time-related individual differences (based on Robertson [1999])

of the two ends of the spectrum. The model is independent of particular disciplines and comprises five indicators, making up the tendency: (i) the preferred mono-/polychronic behaviour, (ii) the reported (actual) mono-/polychronic behaviour, (iii) the feeling towards (comfort with) mono-/polychronic behaviour, (iv) the attitude towards performing many activities simultaneously, and (v) the individual's assessment of the outcomes of mono-/polychronic behaviour, that is to say, the efficiency of time use. The PMTS has been tested in five studies with sample sizes of 133, 141, 201, 322, 375, respectively, and the authors suggest that their result proves a significant improvement over similar time personality models. Unfortunately, the samples were all non-students and adults, that is, the validity of the model for learners is still unproven. Also, cross-cultural studies were not conducted.

Generally, most studies are clearly aimed at economical aspects of time personality and therefore only cover the workplace domain. To date there has been little research on the effects of mono-/polychronicity on learning and student time-management behaviour.

2.3.3 Time Management Strategies and Processes

In order to facilitate the adoption of good time management skills, several time management strategies and processes have been proposed. They are so numerous that this work will only focus on two of them, one primarily used for personal or professional time management and the other in academic contexts.

2.3.3.1 Action Research for Developing Time Management Skills

In his book "Time Management for Academics", Lewis and Hills [1999] describe an action research plan for developing good time management skills. It consists of three aspects, namely observation, reflection, and evaluation. The concrete process then involves 8 distinct steps:

Step 1: State the problem There are several models for this step. In the *demand-supply model*, one distinguishes between demands, supply, and achievements. Demands are usually characterised by a pipeline of tasks to be performed, supply is the human capacity to perform these tasks (the time and effort), and achievements are all completed tasks. Furthermore, there are two control mechanisms, namely (a) to cut the task inflow when the human capacity is reached, or (b) to increase the capacity, that is, to work faster or to drop quality standards so that tasks can be completed more quickly.

The second model is the *ACE model*. It stands for agents, challenge, and environment. The agent is the human being, bringing in their personal knowledge, skills, and working style. The challenge is equivalent to the demand in the first model, that is, an inflow of tasks to be performed. Finally, the environment is the originator of the challenge and the target of the results delivered by the agent; it is normally outside of the agent's control. Again, there are two strategies: (a) the agent must change, for example, by learning new skills or changing their working style, or (b) the challenge must be changed by cutting down the demand.

The *incremental/iterative model* is characterised by a sequential and repetitive learning process. Principally, a task must be performed until the human "succeeds", that is, using multiple iterations. Success in this context must be measurable, in other words, an "improvement" must be detectable. During each iteration, the human attempts to complete the task and notes the effect of their attempt relative to the measure of success. If the task could not be completed, the human approaches the task slightly differently during the next iteration, for example, by planning more time, using different tools, and so on. This model is driven by prompt negative feedback and iterations can become quite long.

Finally, the *NSS model* is a classical input-output model. In the centre, the agent has to deal with a number of challenges, problems, or demands (N), a set of standards for successful and adequate completion (S), and a desirable speed of dealing with challenges (S). Furthermore, the agent produces a result which is (a) the number of completed challenges, (b) their quality, and (c) the time used per challenge. The process is then aimed at optimising the result.

Step 2: Observe the situation This is done on a weekly basis. At first, the user only considers the current week, classifies all due activities, and keeps a diary of all activities including the time used on each activity. This process is then repeated every week.

Step 3: Reflection At the end of each week, the user takes their activity diary and evaluates the situation, for example, they compare the number of successful activities with the number of unsuccessful activities. They also reflect on the time per activity, how it could be optimised, and which issues need to be resolved for this purpose.

Step 4: Plan Using the results obtained in the previous step, the user then composes a plan of action to improve their result. This plan should be fairly specific and can include general as well as activity-specific measures to be carried out in the following week.

Step 5: Carry out the plan The specific plan is then being followed by the user. It should contain a list of to-do items and a schedule for each of them. Suitable tools should be used to aid the user in pursuing their schedule.

Step 6: Monitoring While following the plan, the user reflects on their action. Is the plan carried out correctly? What are the effects?

Step 7: Review The result of the previous step is then used to measure success or failure for each activity in the plan. This requires that they have a well-defined intended outcome which is measurable, that is, there are certain success criteria for every activity.

Step 8: Modify plan The plan should be regarded as a very dynamic artefact. After the activity review, it should be clear whether or not the activity success criteria were met and how to improve the result. This information is then used to modify the original plan. The user then proceeds to step 5 using the new plan.

The aim of this 8-step process is the adoption of certain characteristics of what Lewis and Hills [1999] call a "Master of Time". Masters of time have (1) a personal control room, (2) a personal workspace, and are (3) "out and about". The personal control room is characterised by the user prioritising projects and tasks, planning and acting according to that plan, having a plan for every single day, juggling with different day-by-day demands in an economical way, maintaining documents for control purposes (diary), and being flexible with regard to changes, exploiting every opportunity arising from them. The personal workspace is functional, tidy, up-to-date, and managed using a well-defined system. Furthermore, masters of time fulfil their daily plans, meet their deadlines, keep promises, use meeting time wisely, but can also deal with interruptions.

2.3.3.2 Getting Things Done

A more widely known time management process is "Getting Things Done" by Allen [2001]. His work is primarily aimed at supporting business users in managing their actions in order to become better time managers and complete their work, to "get it done". He describes a new work-life reality: people nowadays are knowledge workers and as a result boundaries between work and free time have vanished. Furthermore, people have to deal with a more quickly changing environment: their job definition, organisation, and careers change more frequently. At the same time, traditional time management strategies and organisation tools can no longer keep up with these rapid changes. For the purpose of addressing these problems, he proposes a five-step workflow process which can be applied to any setting:

Step 1: Collect The user is required to collect "placeholders for or representations of all the things they [you] consider incomplete" [Allen, 2001] using a minimal set of physical, paper-based, electronic, or audio tools, for example, a basket, a software, a notebook, and so on. This involves personal or professional things of any kind. The aim of this step is to get these things out of one's head and transform them into some kind of artefact.

Step 2: Process Once things have been collected, they must be processed in order to be completed. For each item in the collection, the user asks themselves whether it is "actionable" or not, in other words, whether an action is required on this item. In case it is not, it is either disposable (no longer needed, bulk), may be kept for reference, or put aside to possibly deal with at some later time. If it is actionable, the user must decide what action needs to be taken and how long it will presumably take. If it will take less than 2 minutes, the user should do it at once, otherwise they can either delegate it, in which case the item is categorised as "waiting for someone else", or postpone it. Postponement must be terminated, that is, the action must either be scheduled at a specific time or be done as soon as possible. In contrast, if the action involves multiple steps, it should be assigned to a project. A project then contains multiple actions which should be organised in the next step.

Step 3: Organise Following the workflow described in the previous step, delegating, waiting for someone else, putting reminders into a calendar, assigning actions to a project, and managing trash and references are things which need to be organised. Also, within projects, the order of actions and their priority need to be defined. The central activity in this step, however, is to decide on the next action. When putting reminders into the calendar, there should only be three different categories: time-specific actions (appointments), day-specific actions to be done at some time on a particular day, and day-specific information (things of interest related to the day). Allen [2001] argues that organising actions based on this scheme will replace daily to-do lists recommended in traditional time management trainings.

Step 4: Review Enter actions have been processed and organised, they need to be remembered to be completed. Tools – both paper-based and electronic – can support the user in doing this, for example, a calendar and a projects, next actions, and waiting for list. Furthermore, there should be a more detailed review once every week on an elevated level, that is, by (1) gathering and processing all things, (2) reviewing the system itself, (3) updating lists, and (4) clearing up complete and obsolete items.

Step 5: Do Finally, organised actions must be performed at some time. According to Allen [2001], there are three different models for deciding what action to perform at what time. In the first model, the user simply considers their current context, available time and energy, and the priority of the action and chooses an activity based on these four criteria and their intuition. The second model is called the "threefold model" because it knows three kinds of activities to be engaged in: predefined work, doing work as it comes in, and defining work. The first activity is when the user follows their next actions list, the second activity deals with ad-hoc events, and the last activity is when the user clears up their baskets, emails, notes and so on and breaks down projects into actions. Finally, the third model contains six sub-levels, ordered from high to low level: (1) life, (2) three to five-year vision, (3) one to two-year goals, (4) areas of responsibilities, (5) current projects, and (6) current actions. The sixth level contains all actions on any of the user's lists, the fifth the collection of actions making up a project, and the fourth examines what personal responsibilities the user has with regard to each of these projects. Levels 1 to 3 then denote the importance of certain actions.

2.3.4 Project Management vs. Time Management

Similar to time management, project management is mostly seen from a business perspective, that is, with the aim of successfully completing projects in business and industry environments. In contrast, the primary focus of this work is project management in educational contexts, more specifically for the purpose of learning. This is often referred to as project-based learning [Thomas, 2000]. In Chapter 5, the design of a research study around Master of Science summer projects is described. Although such projects do not normally contain collaborative aspects, they are individual projects sharing the same characteristics, hence they fall into the category of project-based learning.

It is important to distinguish between a *project* and *project management*. A project is "an achievement of a specific objective, which involves a series of activities and tasks which consume resources" [Munns and Bjeirmi, 1996], while project management is "the process of controlling the achievement of the project objectives" [Munns and Bjeirmi, 1996]. In other words, the project itself is usually defined by an outcome or deliverable and discrete steps to pursue in order to achieve this outcome. Project management, in contrast, attempts to influence the factors leading towards project achievement. These include planning-related, resource-related, and collaborative aspects. The former aspect usually includes personal as well as group time management. In project-based learning, projects are not only about the outcome but also focussed on a central problem or question students are required to understand and internalise. Apart from the deliverable, the aim is to make students encounter "central concepts and principles of [their] discipline" [Thomas, 2000]. Similarly, project management in these contexts does not only emphasise efficient control of factors leading towards project achievement, but is also designed to make students learn *how* to design, plan, solve problems, make decisions, and work autonomously within a given time frame, often in cooperation with other students. Teachers usually provide guidance on the way, but the main focus is clearly on students' self-exploration and self-regulation. Hence, in this context, time management (see section 2.3) is a sub-discipline of project management since its purpose is efficient use of time in performing project activities.

According to Blumenfeld et al. [1991], projects are also ideal for motivating learners since they are usually designed to engage them in various activities, such as asking questions, discussing and communicating ideas, planning and experimenting, and creating products. These are considerably different from conventional activities performed in the classroom. Furthermore, projects are usually designed using real-life problems which are more likely to be perceived relevant by the student. Another common aspect of such projects is group work, whereby group members usually have a specific role in the project team and take on specific tasks to be performed in cooperation with other team members or individually. Mochizuki et al. [2008] have found that this division of labour entails problems, especially in undergraduate programmes of study, on the grounds that students have a limited amount of time available for getting together as a team to discuss their project. They use groupware technology to mitigate these problems and enhance students' sense of a learning community and mutual project time management practices.

Due to its design and alignment with the software engineering lifecycle, project-based learning is ideal for engineering courses, especially at a more senior level [Dutson et al., 1997]. These courses are then called "capstone courses" and usually take a whole semester to complete; students work on these courses in teams of 4 to 6 on average. Dunlap [2005] found that project-based learning techniques in a software engineering capstone course led to a significant increase in students' perceived self-efficacy, which is one of the key facilitators of motivation.

Ellis et al. [1998] provide a functional classification of tools facilitating project-based learning. These classes of tools are:

- Tools for facilitating group work, such as collaborative drawing tools, electronic whiteboards, virtual group environments. These tools should be deeply integrated into the user's working environment.
- Tools for user guidance and information access: reference material such as the Web or CD-ROMs/DVDs and online or offline search engines.

- Scaffolding tools, that is, tools enabling students' understanding of the subject domain: various interactive and virtual visualisation and experimentation tools, spreadsheets, and problem-solving software.
- Production tools: all tools enabling progress tracking such as word processors, spreadsheets, cameras and recorders, drawing software, etc.
- Communication tools, including human-machine communication for information retrieval, one-to-one communication (email, peer-to-peer software, instant messaging, video conferencing, collaborative editing tools), one-to-many communication (bulletin boards), and many-to-many communication (group conferencing tools, virtual learning environments).

2.3.5 Software Support for Time Management

To mitigate difficulties in time management, software can play an important role. Several approaches have been made in the context of calendar scheduling and study planning. Firstly, traditional personal information manager or groupware applications such as Microsoft Outlook or Lotus Notes can be used. However, these out-of-the-box software solutions lack adaptation capabilities and have been specifically designed for use in the professional workplace. Furthermore, Blandford and Green [2001] found that users prefer the use of a "battery of tools as an ensemble" for time management.

Mitchell et al. [1994] emphasise the importance of adaptation for such applications and developed an interactive learning assistant called CAP (Calendar Apprentice). CAP passively learns patterns (duration, location, day of week, and times) for calendar appointments from user input by using decision trees. It is also suggested that time-related individual differences (mono/poly-chronicity, see section 2.3.2) should also be considered in such applications [Lee, 1999, 2003], and that temporal behaviour of workers in an organisation can change dependent on the current context or activity.

Similarly, Rebenich and Gravell [2008] presented an adaptive time management system for student learning. It takes the student's learning style using the Index of Learning Styles [Felder and Silverman, 1988; Soloman and Felder, 2001], matches it with the teaching style of a module, and creates an individual study plan based on the differences between the two styles and a user-defined set of learning tasks. While following the plan, the student gives regular feedback about task progress. Using this feedback, the system automatically adapts the study plan by means of a multi-layered neural network and an iterative back-propagation learning algorithm. The desktop application is complemented by a mobile application using GPS data to issue position-related reminders, however, this mechanism was found to be unreliable and very power-intensive. While the practical applicability of the system framework was shown, a thorough evaluation and research study were not conducted.

Context-based resource discovery and reminder services have also been attempted by Byun and Cheverst [2001]. In their Personal Digital Secretary (PDS) system architecture, a context model containing data retrieved from sensors is used in combination with a traditional user model. The system tries to predict the user's possible future behaviour based on the context, past events which happened in that context, and a predefined schedule. Here, context refers to the user's current location and all available information about resources associated with it. The system then launches reminders based on that prediction and uses user feedback upon these reminders for system adaptation. At the same time, the user can access a history of past activities or events performed in the current context.

In an educational domain, Leung and Li [2003] use a dynamic conceptual network of programmes, courses, and credit units to develop a personalised study plan for students. Personalisation in this context means that the system presents the subset of the conceptional network best fitting the student's academic background and learning goals.

Martin et al. [2006b] utilise the user's context information in combination with a learning activity agenda, which helps determining learner availability in a particular situation, and their idle time in order to propose situational learning activities to the learner. Learner characteristics such as learning style and collaborative learning aspects are also considered. However, the main focus of their architecture is on context-aware learning activity adaptation. This mechanism is based on rules such that activities are only suggested if certain context-specific or general conditions apply.

Sharples [2000] proposes the use of mobile technology for lifelong learning, that is, learning "from cradle to grave" [Johnston, 2003]. His framework, which later led to the development of concrete learning organiser software [Holme and Sharples, 2002; Vavoula and Sharples, 2002; Corlett et al., 2004; Chan et al., 2005], is based on the idea of constructivism, enabling a dialogue between teacher and learner in order to enable reflection. It addresses the key requirements of lifelong learning and suggests that software should take the role of a mentor, providing dictionaries, bibliographies, concept maps, learning organisers and schedulers, visualisation tools, and project management capabilities. Based on Sharples's theory, a number of prototypes were developed.

First, Vavoula and Sharples [2002] presented KLeOS, an application focussing on learning projects, learning episodes taking place within them, and learning activities associated with an episode. As a student performs learning activities, the newly gained knowledge is visualised on a knowledge map and time line. The former is linked to the episodes and projects, so that the user can trace which episodes contributed to a particular knowledge aspect.

Then, Holme and Sharples [2002] and later Corlett et al. [2004] worked on another student learning organiser software, developed for a Microsoft Windows Mobile compatible PDA, harnessing the functionality of existing personal information manager applications (here: Microsoft Pocket Outlook). The tool consists of a time manager displaying course timetables and deadlines, a course manager which is used to access course material, a communication tool, and a concept-mapping tool for organising notes and documents. The latter had usability issues, partly due to a lack of concept mapping skills [Corlett et al., 2005] on the part of the user. Student feedback at the end of a ten-month trial revealed that timetable and communication tools were used significantly, but also that more research is required on the integration of study organisation tools into traditional personal information managers, and on adaptation to learner model and context.

Finally, Bull et al. [2005] present TenseITS, a system aimed at enabling their users to learn whenever and wherever they want by pointing out so called *learning opportunities* fitting into their daily schedule. This is combined with traditional intelligent tutoring techniques. Rather than detecting the current learner context through sensors (for example a GPS receiver), the system expects this data (location type, concentration level, interruption likelihood, and available time) to be provided manually by the learner. Moreover, the system contains a learner model-like structure denoting the user's knowledge level. In the course of user-system interaction, instruction and concepts to be taught are adapted to learner context and the learner model.

In project-based groupwork contexts, Mochizuki et al. [2008] use groupware techniques to enhance student project planning. They found that undergraduate students often struggle to come together and discuss their progress on groupwork assignments. As a result, it often happens that some group members are more active than others, and that project deadlines are missed due to some members' inactivity. To address these issues, they developed a web-based groupware application for project-based learning called "ProBo", and a complementary mobile version "ProBo Portable" which can be used on mobile phones. The system allows students to (a) organise division of labour on group tasks and provide feedback on their progress, (b) display a task tree showing task interdependencies, (c) schedule tasks on the time line, and (d) share electronic resources associated with these tasks. The mobile application keeps individual group members informed about the progress of each member on their project tasks. Mochizuki et al. [2008] found that the use of this system increased students' progress awareness, encouraged them to work on their tasks since other users would immediately notice when they fall behind, and improved in-group communication. In their experiment, the group using ProBo Portable also reported an increased "sense of learning community", higher connectedness, and enhanced learning.

2.4 Social Presence and Awareness

The term "social presence" was coined by Short et al. [1976] and refers to "the degree of salience of the other person in the interaction and the consequent salience of the interpersonal relationships" [Short et al., 1976] in communications using a particular medium, for instance, face-to-face, the telephone, or online. Therefore, social presence is an important aspect of educational computer systems. It is based on the theory of communication efficiency and non-verbal communication. The former refers to the distinction between medium-sensitive and medium-insensitive tasks. While in medium-sensitive tasks interpersonal relationships between participants are important, medium-insensitive tasks involve only cognitive material and thus these relationships are less important. The latter theory (non-verbal communication) deals with non-verbal cues exchanged between the communication participants. There are three types of non-verbal cues, namely (i) cues transmitted by all media, (ii) cues only transmitted face-to-face, and (iii) cues distorted in transmission. All cues are perceived in combination and the participants adapt their behaviour to the communications medium they are using, for instance, on the telephone they are likely to replace head-nods by verbal phrases like "I agree" or "absolutely". Also, cues are context-sensitive, that is, they do not have the same meaning across situations.

The social presence theory implies that there are two aspects in such person-to-person interactions, namely interparty exchange (a person acting out a role) and interpersonal exchange, which are affected by the communication medium used. Telephone conversations, for instance, are more task-oriented, and therefore there is more emphasis on interparty exchange. Social presence is then defined as an attribute of the medium used in the interaction referring to its subjective qualities in terms of the purpose of the interaction. More specifically, it is a user's "mental set" towards the medium, which can be measured by using four 7-point, bipolar scales: unsociable-sociable, insensitive-sensitive, cold-warm, and impersonal-personal. High social-presence media are therefore described as sociable, sensitive, warm, and personal. Experiments conducted by Short et al. [1976] have also shown that social presence tends to fuse with an "aesthetic appeal" factor with regard to the medium in cases where the set of available communications media is limited.

Now, the above definition of social presence was created at a time when video-phones and conference telephone calls had just been introduced and become available to business users. In the light of more advanced communication technologies, the definition of social presence has been extended and shifted towards "the combination of skills and abilities which allow them [participants] to achieve salient interpersonal interactions" [Kehrwald, 2008], the degree to which individuals perceive the tangibility and proximity of other users involved in the communication, and the participants' social and emotional projection ability in a community. Clearly, this definition describes relational aspects of the communication rather than the medium itself. In other words, face-to-face communication, which according to Short et al. [1976] has the highest social presence, is used to benchmark other media. This new definition of social presence was the result of a study conducted by Kehrwald [2008] with the aim of understanding how online learners experience social presence in computer-mediated communication. The study data was collected from a learning management system over a period of one calendar year. Further data was collected through questionnaires, one-to-one interviews, and group discussions. The study results also enabled Kehrwald [2008] to identify three important ways to promote the development of social presence in an online learning community:

1. The ability of participants to send and receive cues. Such skills are not present in novice learners and need to be learnt.

2. The opportunity for interpersonal interaction between participants, which can be facilitated by promoting productive interactions, by avoiding overwhelming demands of interaction, and by balancing flexibility and structure. Clear instructions and guidance with regard to interaction opportunities should be given.

3. The motivation of participants since such interaction does not happen spontaneously but requires time and effort. Motives can be *need*, for instance, if a task requires participants to interact with one another, or *interest* (see section 2.2). Interest can be aroused through feedback requested by other users or other users' feedback.

In the context of learning support systems, Cao and Crews [2009] examined the impacts of social presence on user interaction by reviewing media richness theory [Daft and Lengel, 1984]. According to this theory, different media can convey different communicative cues such as body language, facial expressions, and tone of voice. The more cues a medium can carry the richer it is. Then, in turn, the richer a medium the better its task performance. Face-to-face communication is therefore considered the richest medium, while video telephony is richer than audio telephony, which is, in turn, richer than email communication. Formal written communication thus constitutes the least rich medium. Cao and Crews [2009] then used a field experiment involving 120 participants to test the social presence of email-based interaction compared to that of interaction with a virtual automated instructor, and the effect of either interaction on user satisfaction, perceived learning effectiveness, and actual learning performance. The results suggest that the perceived social presence of email-based interaction is slightly higher than that of virtual interaction. Email-based interaction also yields a higher user interaction and a higher perceived learning effectiveness. However, no significant relationship was found with actual learning performance. These findings are important because they show that there is a difference between objectively measured social presence of a medium as defined by Short et al. [1976] and the new definition of social presence provided by Kehrwald [2008]. Also, one would have expected virtual interaction to yield higher perceived social presence because this medium can carry more cues.

Based on Kehrwald's new definition of social presence, some technological enhancements have been attempted. For instance, Eisenstadt and Dzbor [2002] use the term "enhanced presence" referring to the provision of geographical data and the status of resources in an instant messaging network. The communication medium is synchronous text-based messaging, and user presence is given by their online status, their current geographical location, and resources available in their area including their availability. User location is fairly fine-grained, that is, other users can see their location at the inside of building layouts. The visualisation of these aspects is claimed to motivate and sustain interpersonal interactions between geographically distributed users and enable spontaneous interactions and group formations among connected users. Bai [2003] supports this claim, indicating that enhanced presence can promote user motivation.

Similarly, El-Bishouty et al. [2006] present the idea of knowledge awareness. In their "Perkam" system, which was implemented on a Windows Mobile platform, the availability and geographical location of knowledge (people, material) in the area is visualised by using knowledge maps, enabling learners to locate and contact other learners, exchange knowledge, and collaborate. Their knowledge map is still very simplistic as it only shows the relative distance between the learner and knowledge resources in a two-dimensional coordinate system.

The implementation of social presence was important for the online systems used in both research studies presented in Chapters 4 and 5.

Closely related to the concept of social presence in multi-user and collaborative learning environments is the concept of *awareness*. Awareness in this context refers to one's "understanding of the activities of others" [Dourish and Bellotti, 1992], yielding the context for one's own activity. It has been identified as a crucial driver for collaboration in writing [Dourish and Bellotti, 1992], groupware systems [Gutwin and Greenberg, 1996; Pinheiro et al., 2003], their mobile equivalents [Kirsch-Pinheiro et al., 2004; Khan et al., 2008], and educational groupware systems [Gutwin et al., 1995]. Against this background, awareness is different from social and enhanced presence (see previous section) in that it incorporates aspects beyond those enabling user interactions. However, the term *awareness* is used in a variety of different contexts, sometimes even in contradictory ways [Schmidt, 2002]. While some sources use it to denote passive information gathered automatically in the background while activities are in progress, others describe awareness as a subtle attunement of displaying and monitoring of user activities in a shared context with the aim of creating an environment which is "infinitely rich in cues" [Schmidt, 2002]. More specifically, Brézillon et al. [2004] describe awareness as the process of capturing user interactions with the system, visualising them in a suitable way, and most importantly their interpretation by system users (see Figure 2.4.1).

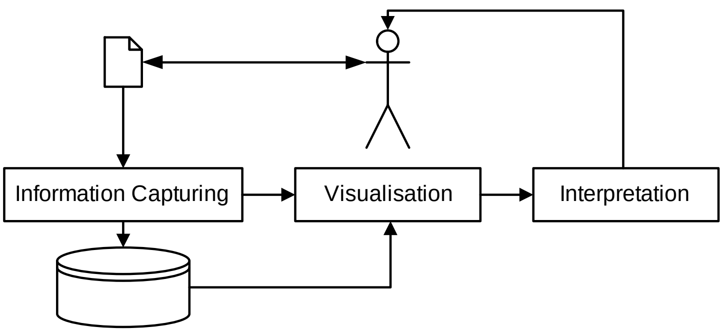


Figure 2.4.1: Awareness (based on Brézillon et al. [2004])

In electronic multi-user systems, awareness is used to enable and enhance activity co-ordination between users, their collaboration on such activities, and information sharing [Dourish and Bellotti, 1992]. According to Markopoulos [2009], other benefits of awareness in group-based systems are:

- Enabling users to find out more about one another and share experiences
- Providing information about users' current activity, location, and status or availability
- Generating a feeling of connectedness and empathy amongst users
- Enabling group formation and community building

Traditionally, the concept of awareness has been used in computer-supported cooperative work for enabling cooperating users to align and integrate their work without interrupting one another [Schmidt, 2002]. This is said to generate "informal interactions and a shared culture" [Schmidt, 2002] and hence to enhance cooperation between users. For this purpose, computer systems use event propagation mechanisms to collect, disseminate, and integrate information about activities users collaborate on. Pinheiro et al. [2003] suggest that information about activities displayed to users must be appropriate and relevant to the specific role they play with regard to the group, otherwise there is a risk of cognitive overload, which might negatively affect the group. Different applications of awareness technologies have been presented in literature. For example, Dourish and Bly [1992] use a system called "Porthole" to facilitate awareness in distributed group-based systems. More specifically, video technology is used to give distributed users the feeling of a shared workspace. While no statistical evaluation of system effects on user behaviour was conducted, they claim that "experience" suggests a positive system effect on user communication and interaction. Similarly, Geyer et al. [2001] propose a web-based "TeamSpace" system for virtual meetings, in which users can manage so-called "articulation objects" in synchronous online meetings or recordings of such meetings. However, the system prototype used in their study was unstable, which heavily affected its overall usefulness. Finally, Chiken and Hazeyama [2003] presented a group based system for supporting software engineering projects in higher education by means of text-based discussion on artefacts, browsing awareness showing users who accessed certain artefacts, and artefact inspections by teaching staff. In their evaluation, all three features were rated useful or very useful by students.

In principle, there are two ways of implementing awareness [Dourish and Bellotti, 1992]: (i) explicit information generation and (ii) passive information collection and distribution, also referred to as implicit information generation. In the former case, the user explicitly generates the information and makes it available to other users in the same work space, and in the latter case, the information is implicitly gathered by the system during a user activity and then made available to other users. While explicit information generation requires users to interrupt or defer their current activity for the purpose of generating information, passive information collection happens autonomously in the background and without direct user involvement.

Furthermore, Markopoulos [2009] mentions a third type of awareness implementation, which falls between explicit and implicit information generation. This form of awareness enables users to generate information in a non-focussed and incidental manner with minimal effort, that is, the communication of such information is a secondary activity taking place quasi-simultaneously while a primary activity is being performed.

In summary, three different types of awareness implementation can be identified: (i) explicit and intentional information generation, (ii) incidental information generation, and (iii) implicit information generation.

Moving away from this rather technical view on awareness, Gutwin et al. [1995] identify four types of awareness in the educational domain. These are

1. Social awareness: a student's expectation from other students, their interaction with and role in the group, and the role other students assume them to have.

2. Task awareness: the student's and other students' knowledge of the topic, the structure of the task, and how it is assessed, the steps leading towards task completion, how much time is needed and available, and resources necessary to complete the task.

3. Concept awareness: how does the task fit into the student's present concept knowledge and the task's implications for revision of current ideas and outcome prediction.

4. Workspace awareness: other members' past, current, and future activities in general and with regard to the task, their location, and opportunities for supporting the group.

In this context, three examples of using data visualisation for raising user awareness are given. Firstly, in their mobile extension to an online groupware for project-based learning, Mochizuki et al. [2008] use a wallpaper layout to display the progress of students working together on a group project. They use box shapes to visualise tasks and colours to denote deadlines. Furthermore, a score shows how each project member performs compared to the others. It was found that these techniques enhanced students' awareness of their own progress and that of other group members, encouraged them to work on their tasks, improved in-group communication and their "sense of learning community", and eventually led to higher connectedness and enhanced learning.

Secondly, the work of Hatziapostolou and Paraskakis [2010] also uses visualisations of student performance indicators as part of an online formative assessment system in the context of an undergraduate BSc in Computer Science course. In particular, the system displayed histograms depicting grade category distributions and detailed lists of student grades per assignment, provided that the module leader explicitly enabled such visualisations. Although no detailed research study was conducted, usage data analysis of two consecutive academic years suggests that (i) all students accessed online feedback submitted by their lecturer, (ii) about a third of all students revisited the system before their final exams, possibly for the purpose of exam revision, (iii) students perceived the system motivational, and (iv) students who used the system indicated that online feedback was prompt and efficient in their end-of-semester module evaluation. The authors also claim that their system is likely to enhance motivation, but no objective evidence was established using further analysis.

Thirdly, Govaerts et al. [2010]), used visualisations for the purpose of enhancing learner self-monitoring, student time-on-task tracking, teacher awareness, and learning resource recommendations. The underlying data originates from a personal learning environment (PLE). Visualisations used are (i) statistic listings of student time and document usage, (ii) document recommendation panes, and (iii) line as well as bar charts depicting individual student time usage. While usability tests were performed using 12 computer science students, yielding a high usability on average, possible effects of these visualisations on student behaviour, especially time management and study planning, were not evaluated.

2.4.1 Web 2.0 Technologies

Web 2.0 is a very loosely defined term, first used by DiNucci [1999], referring to the Web as a transport mechanism rather than screens of text and graphics. However, there is still a lot of discussion of what exactly the term means. O'Reilly [2007] suggest that the easiest way to understand Web 2.0 is to contrast it to its predecessor (Web 1.0). The main advantages of Web 2.0 over 1.0 are (i) harnessing collective intelligence by using network effects from user contributions (blogging, wisdom of the crowds), (ii) managing huge amounts of data, (iii) providing software as a service, (iv) enabling lightweight programming (scripting, XML, AJAX, etc.), (iv) supporting platform and device independence, and (v) creating rich user experience (rich user interfaces, participation, adaptation) [O'Reilly, 2007].

The Web 2.0 idea of user participation has led to researchers examining the use of Web 2.0 in the educational domain to enhance learning. Educationalists have understood that Web 2.0 features "appeal" to learners and that traditional learning management systems lack such features but are inflexible and focus too much on institutional practice than student needs [Sclater, 2008]. In line with the idea of self-regulated learning, Downes [2005] use the term "E-Learning 2.0" to refer to a new learner-centred design of e-learning systems, placing the control of learning to the learner with the aim of empowering the user and decentralising of authority [Collis and Moonen, 2008]. In this context, Web 2.0 enables information to be "created, shared, remixed, repurposed, and passed along"

[Downes, 2005]. Ultimately, this is believed to lead towards "Education 2.0", using technologies such as blogging, podcasting, creation of learning content by learners, personal learning centres, portfolio tools, and the syndication of content. In this new learning environment, the idea of "social learning" is key [Ebner et al., 2007]. Besides being a cognitive process, learning is also a social process, involving conversation and interaction between learners. Such interactions can take place with content, the instructor, other learners, and technology itself. At the University of Graz (Austria), Ebner et al. [2007] used common Web 2.0 tools such as web logs, file sharing, student portfolios, community blogs, RSS news feeds, and tagging in a personal learning environment and found that the most important factor for these tools to be effective is their ease of use.

Safran et al. [2007] also note the change of learning towards knowledge-centredness, whereby learners collaborate and make active contributions to the learning content. They distinguish between technological and social aspects of learning. Technological aspects are learner interaction such as discussion, commenting, and collaborative writing (supporting a socio-constructivist pedagogical strategy), the production of learning content, subscription to news feeds, and student portfolios. In contrast, social aspects refer to the interlinking of learners, enabling users to find other learners on the same or similar courses or with shared interests, sharing multimedia content, and bookmarking.

While most research in the area of Web 2.0 in educational contexts seems to focus on active learner contribution to the learning content and learner collaboration, this work utilises Web 2.0 technologies for supporting social aspects of learning, more specifically the interlinking of learners, and the creation of a common learning space and awareness context. For this purpose, technologies listed by O'Reilly [2007] will be used to support user awareness as shown in Figure 2.4.1 on page 59.

2.4.2 Context-Awareness

By virtue of more sophisticated mobile technologies and more affordable mobile devices becoming available, there is an obvious trend towards using awareness techniques in mobile e-learning applications; this is then called *m-learning*. In particular, m-learning tools use the learner's current context to adapt material and/or learning activities, they are *context-aware*. It is claimed that this allows learners to gain learning experiences at any time and any place, and helps them save time [Martin et al., 2006a].

Although the focus of this work is not specifically on m-learning, context-awareness features (geographical location and its visualisation) are used in the first experiment prototype described in Chapter 4. Furthermore, the use of mobile devices by students was evaluated using the time management technology survey covered in Chapter 3.

The notion of *context* is not universally defined. Schilit [1995] suggests that context is a set of information types available in a particular situational context. These are physical objects (including people) in the area, the current state of the device holder and their geographical location, environment factors such as noise, activities normally performed there, and desired system behaviour. Similarly, Schmidt et al. [1999] point out that context is not only about geographical location, but "describes a situation and the environment a device or user is in", and consists of a set of features each holding a range of possible values. Their model of context distinguishes between human factors and the physical environment, the former referring to the user (habits, emotional state), the social environment (people nearby and their relationship with the user), and spontaneous or planned tasks (possibly derived from goals). The physical environment is defined by geographical location, its characteristics (infrastructure and available facilities), and current physical conditions (noise, light, pressure, temperature, weather). Physical conditions can have a fine-grained structure of sub-attributes. Furthermore, the context changes over time and hence there is a history of context states on the time line. However, the accuracy and amount of context information is dependent on the number and quality of available sensors, as well as on the demands of the systems using this information.

A number of m-learning systems already use context-awareness techniques. The architecture proposed in [Martin et al., 2006a, b] harnesses learner context, defined by geographical location, spare and idle time, and available devices in the area, as well as the context of other learners in a group and suggests learning activities to be performed in the current learner situation. The system adaptation is based on the context, a domain model including rules used for determining suitable learning activities, the learner model, and the group model containing relationships to other learners and each learner's role in the group.

Rebenich and Gravell [2008] use context-awareness techniques for issuing position-related reminders in their adaptive time management system for student learning. The system uses the student's learning style, compares it to the teaching style of module, and schedules a set of user-defined tasks based on the difference between the two styles. Users can associate learning tasks with a specific location which is, in turn, associated with a GPS position. The schedule is continuously adapted using machine learning while the student follows the plan and synchronised with a GPS-enabled PDA. In case a scheduled task is associated with a location, the system will issue a reminder if the user is not at the specified place at the right time.

Albeit not specifically addressing m-learning, Marmasse and Schmandt [2000] focus on information delivery based on the current user location. Their *comMotion* system allows a set of to-do items to be attached to a geographical location, alerting the user once they are in the area. Furthermore, information about local facilities is retrieved from the internet, and reminders from other users logged onto the system can be received. Similarly, the *ConChat* system presented in [Ranganathan et al., 2002] uses a rule engine based on predicate calculus and Boolean algebra to enable context-aware chats between users. The context is defined by aspects such as location, number of other people in a space and their identities, physical conditions (light, noise, and so forth), user mood and status, and the activity currently taking place in that space. The application allows all participants to implicitly query this contextual information and thus gain a much more real chat experience.

In [Ogata and Yano, 2004], a context-aware system for learning Japanese polite expressions, called JAPELAS, is presented. The application especially addresses overseas students who are not familiar with polite expressions in the Japanese culture, which can vary significantly dependent on for example social distance and formality of situation. Again, a rule-based system is used in combinations with GPS and RFID technology to make recommendations to the learner about which polite expression to use in the current context.

2.5 Feedback and Monitoring

Feedback is defined as "all dialogue to support learning in both formal and informal situations" [Askew, 2000]. It is said to be an "inherent catalyst" for self-regulated learning activities [Butler and Winne, 1995] and can originate from external and internal sources. Internal feedback is the result of a process called *monitoring* which is described later in this section.

According to Butler and Winne [1995], feedback is hypothesised to be more effective if preceded by task planning in which course concrete performance criteria are generated. Feedback from external sources has also been found to be effective, provided that it is given during learning activities and not – as traditionally the case – after task completion. As synthesised by Butler and Winne [1995], there are two types of feedback:

1. The simplest type is *outcome feedback*, whereby the only information provided is the current state of task achievement and no further information about possible ways of improvement is conveyed.

2. *Cognitive feedback* is more elaborate, whereby a set of cues indicating progress is provided and linked with learner achievement. This type of feedback has three sub-types, namely (i) task validity feedback, making the learner aware of the relationship between a task cue and the likelihood of successful task completion, (ii) cognitive validity feedback, describing the learner's own perception of the relationship between task cue and achievement, and (iii) functional validity feedback indicating the relationship between the learner's achievement estimate and their true performance.

The process of generating feedback is often referred to as *monitoring*, which is described as "the cognitive process that assesses states of progress relative to goals and generates feedback that can guide further action" [Butler and Winne, 1995]. The underlying cognitive process is depicted in Figure 2.5.1. Strategic planning in the forethought phase generates a set of goals including a set of goal characteristics denoted as goal profile and tactics or strategies for achieving those goals. This also results in a set of tasks and sub-tasks to be performed in order to achieve a goal. Then, self-recording in the performance and self-evaluation in the self-reflection phase yield the task outcomes and the current state of task completion. In the recursive monitoring process, discrepancies between intended and current task states and outcomes are evaluated, affecting the learner's self-reaction towards goals, tactics, and strategies.

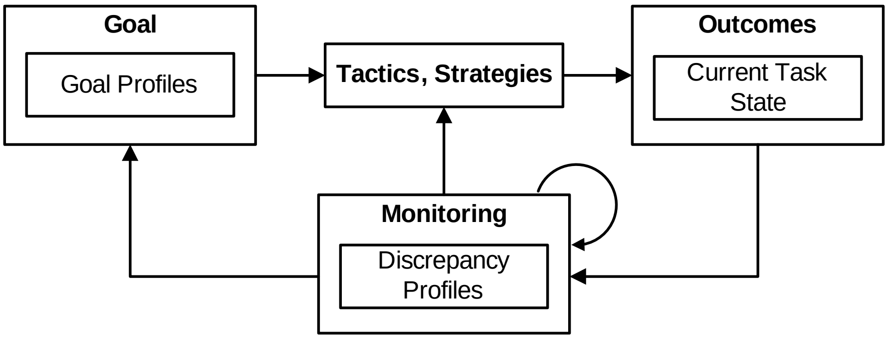


Figure 2.5.1: Monitoring and resulting cognitive processes (adapted from Butler and Winne [1995])

Feedback is a fairly complex topic in itself. The work presented in this thesis focuses on the monitoring process of self-regulated learning rather than the nature of feedback itself. However, it is noteworthy that substantial research has been conducted in this area in recent years. Carless et al. [2011], for example, outline the importance of feedback for student learning and describe it as "one of the most problematic aspects of the student experience". This is supported by data from national student surveys, for instance that published by the Higher Education Funding Council for England [HEFCE, 2011], in which many institutions still score low with regard to the promptness and quality of feedback. Carless et al. [2011] also suggest that feedback should be designed as a "dialogic feedback cycle" rather than uni-directional information transmission from teacher to student. The increasing value of technology-supported feedback is also stressed. Online dialogue systems have been found to be more effective than conventional verbal and textual feedback [Carless et al., 2011]. Furthermore, such systems enable feedback to be available much more promptly. A literature review conducted by Hepplestone et al. [2011] revealed that computer technology is already widely used for this purpose and that it is hypothesised to "have the potential to enhance student engagement with feedback". Applications range from uni-directional feedback systems (the teacher submits feedback, the student reads it in privacy), over dialogue-based systems, artefact annotation, computer-aided assessment, to peer assessment systems.

2.6 The Seven Principles

To address the problem of "pathetic", "illiterate" students and "incompetent", "impersonal" teaching and teaching environments, Chickering and Gamson [1987] propose the implementation of seven principles for good practice in undergraduate education. They are to be seen as guidelines for faculty, students, and administrative staff to improve both teaching and learning, and based on six “forces” in education, namely activity, cooperation, diversity, expectations, interaction, and responsibility. Therefore, they play an important role in the design of educational software used by such institutions. Derived from the six forces, the seven principles are:

1. *Encouraging student-faculty contact* with the aim of increasing student motivation and involvement
2. *Development of student cooperation* in order to increase student involvement and understanding
3. *Use of active learning techniques* such as discussion, structured exercises, writing, and group work
4. *Provision of prompt feedback to students* so that they can reflect on their progress and performance and to give them the chance to improve
5. *Putting time on task first* to foster effective time management
6. *Communication of high expectations* so that all participants in the learning process are encouraged to make extra efforts
7. *Respect of diverse talents and learning styles* enabling students to learn in ways which work best for them

They also comment on the characteristics of environments fostering the adoption and effects of the seven principles. In particular, such environments should (i) have a “strong sense of shared purposes” [Chickering and Gamson, 1987], (i) employ staff supporting these purposes, (iii) provide adequate funding, (iv) have consistent policies, and (v) apply continuous control of purpose achievements.

In later work, Chickering and Ehrmann [1996] make concrete proposals regarding the implementation of the seven principles using computer technology, which are summarised in Table 2.5. Furthermore, they suggest that the use of technology itself is not enough: it should be embedded into both a teaching strategy and formal course requirements.

The importance of such strategies is further emphasised by Ehrmann [1995]: “what matters most are educational strategies for using technology, strategies that can influence the student’s total course of study”. In this context, he criticises that it often takes too long to develop and adopt specific software applications for learning, and that these applications are quickly outdated due to rapidly changing technologies, platforms, and operating systems. What is more, the process of faculty and user acceptance of such software is often time-consuming and requires support from a considerable number of staff in the faculty as well as sufficient funding. Furthermore, learning software can

Table 2.5: Implementing the seven principles [Chickering and Ehrmann, 1996]

#	Principle	Suggested Technology
1	Student-faculty contact	Electronic mail, online conferencing, the Web
2	Student cooperation	Electronic mail
3	Active learning techniques	Tools supporting learning by doing, time-delayed exchange (forums), real-time conversation, word processing
4	Prompt feedback	Electronic mail, tools for recording/analysing personal performance
5	Emphasising time on task	Repositories (access to materials anywhere, any time), tools for recording participation and interaction, task management systems, asynchronous communication (electronic email)
6	High expectations	Tools demonstrating real-life situations, larger data sets, the Web as a platform for peer evaluation
7	Talents and learning styles	Tools supporting different ways of material presentation, adaptive systems, collaborative systems

shape the way a particular subject or course is taught, incurring additional risks for the institution and students. According to Ehrmann [1995], these are the most prevalent obstacles to overcome when developing and establishing curricular learning software in the institution.

2.7 Summary

This chapter has provided a comprehensive overview of self-regulated learning and four main aspects thereof: motivation, time management, social presence and awareness, and monitoring/feedback. Furthermore, seven principles of good practice in undergraduate education were presented.

The remainder of this work will focus on providing technology support for these four main aspects, which are therefore referred to as *technology-supported learning aspects* (TSLAs) throughout this thesis. The emphasis is on how technology can be used to enhance these aspects in the context of self-regulated learning in higher education (see Figure 2.7.1). While there is substantial prior research on how these aspects can support student collaboration, little work has been conducted in hybrid settings (traditional teaching with project-based learning and/or student collaboration) or in environments where the focus is on individual project work only. One reason might be that group dynamics are more obvious and can be observed more easily in purely project-based or collaborative settings, that is, in learning environments entirely focussed on group work. The four main TSLAs are summarised in the following paragraphs.

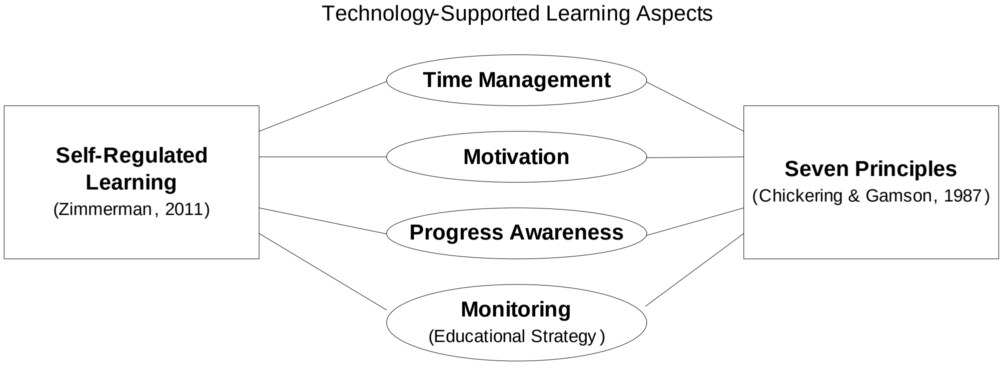


Figure 2.7.1: Technology-supported learning aspects (TSLAs) and how they relate to self-regulated learning and the Seven Principles

Time management was found to be an essential soft skill for university students. It is associated with less stress, higher self-confidence and control over time, higher quality output, and increased academic performance. However, it is still a common issue encountered by many students. A number of different strategies for effective time management such as "Getting Things Done" were devised to mitigate these problems. Time management is also an important factor in project-based learning contexts where the focus is on learner autonomy, self-regulation, and motivation. Besides traditional time management applications, which were designed for the professional workplace, a number of approaches have been made to provide software tailored to student needs. Prominent examples are simple timetabling tools, mobile applications, and groupware systems used in project-based learning. Few of these approaches have been evaluated empirically. In self-regulated learning, time and project management are important for task analysis, goal setting, and strategic planning in the forethought phase, and also for task strategies and following the strategic plan in the performance phase, that is, when students work on their learning tasks.

Motivation is an equally important factor for learning. It is influenced by the degree of learner autonomy and content relevance. Motivated learners were also found to be less likely to procrastinate. In section 2.2.1, two different kinds of motivation (intrinsic and extrinsic) were introduced, while section 2.2.3 outlined the extent to which the three schools of learning (behaviourism, cognitivism, and constructivism) foster learner motivation. Motivation theory has also led to the development of several motivational models which are used in software aimed at detecting and instigating learner motivation. In self-regulated learning, students' self-motivation beliefs are made up by students' self-efficacy, that is, the confidence in their ability to achieve a result, their expectancy regarding the outcome, their interest in the task itself, and their goal orientation. Students can be focussed on learning the material (learning goal orientation) or on their achievement in relation to others (relative ability goal orientation). Empirical research on these two types of goal orientation have produced mixed results regarding their effect on students' self-motivation beliefs. Some sources state that learning goal orientation is more effective than relative ability goal orientation while others did not find any difference. Relative ability goal orientation is also influenced by information about other learners' performance in the same learning environment, which is described in the next paragraph.

Two techniques for instigating and maintaining motivation are *social presence and awareness* which were introduced in section 2.4. Social presence is important for enabling user interactions in virtual multi-user environments. It can be enhanced by disclosing contextual information, yielding to enhanced presence, which is claimed to have a motivating effect. Awareness goes beyond user interaction and enables coordination, information sharing, feelings of connectedness and empathy, group formation,community building, and motivation. More specifically, user interactions with a learning system are captured, visualised, and interpreted by the same or other connected users. In the context of this work, the visualised data originates from progress feedback and is used for raising students' awareness of their own progress in relation to others; this is referred to as *progress awareness*. In computer technology, social presence and awareness can be implemented using several techniques such as data visualisation, progress information disclosure in project-based learning contexts, and harnessing context data (for example GPS location data). Awareness also requires users to actively participate and contribute, which can be facilitated by using Web 2.0 technologies (see section 2.4.1) such as news feeds, commenting tools, and discussion features. One aim of this work is to show how awareness technologies can be harnessed to support students' self-observation in the performance phase and their self-judgement in the self-reflection phase.

Another important TSLA is *monitoring* which was introduced in section 2.5. Monitoring is the process of generating *feedback*, both by the student and external sources. In self-regulated learning, the former is referred to as self-observation in the performance phase. More specifically, self-regulated students use metacognitive monitoring whilst performing learning activities, constantly recording the current state of learning tasks and whether they are on track towards the goal. This information is complemented by external feedback from mentors, teachers, and other students, affecting the learner's self-evaluation and causal attribution in the self-reflection phase. This, in turn, affects their reaction in the next cycle of the learning process. Feedback generated in the monitoring process can be visualised as described above and lead towards students' awareness of their own progress.

Finally, the seven principles for good practice in undergraduate education were presented. They are aimed at improving educational environments for the benefit of both learners and teachers. As such, they are important when designing software for this domain. Furthermore, all technology should be embedded into an educational strategy. This thesis also examines how technology can be used in self-regulated learning so that it is in line with the seven principles, and which of these technologies effectively support those principles.

Based on this review, and with regard to the TSLAs introduced in this section, the following predictions concerning expected effects of software tools on student time management, motivation, and performance can be made:

1. Tools for time management such as schedules, calendars, and task lists support student time management, which is important for strategic planning and during task performance. They can also be used to enhance student self-monitoring by providing achievement and progress data. Expected effects are improved time management and higher performance.

2. Tools for capturing and visualising progress awareness data, for example news feeds, interactive tools, feedback submission tools, charts, and performance scores, support students' relative ability goal orientation and self-monitoring, and are likely to positively affect student motivation and performance.

3. Monitoring tools enhance the generation of internal and external feedback and also support students' self-observation and reflection. Therefore, they are expected to improve time management, motivation, and performance.

Chapter 3

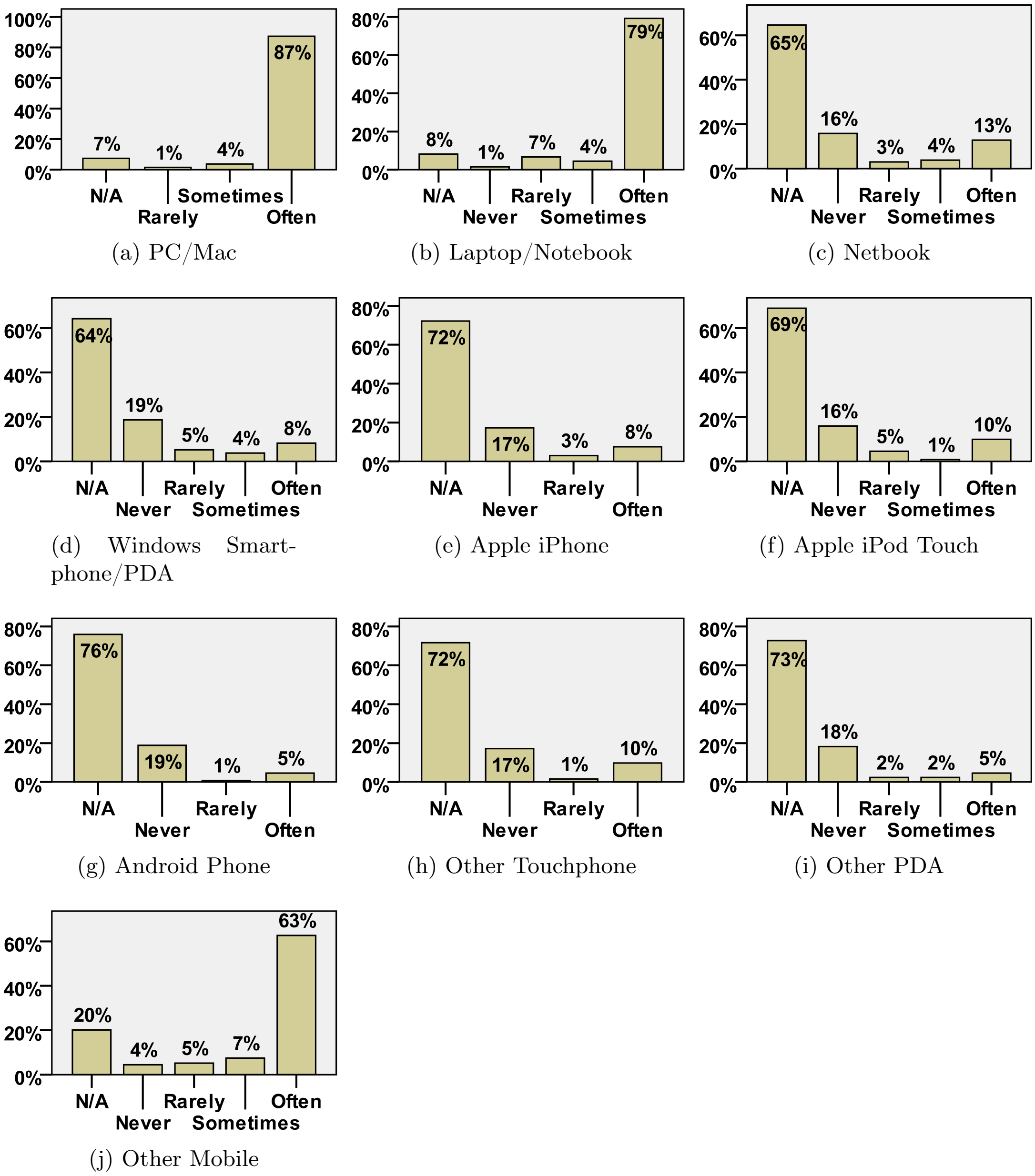
Survey of Students' Technology Use for Time Management

In order to understand what time management practices students use and to what extent, a survey was conducted, aimed at evaluating the current use of mobile computing devices, calendaring software and their features, student study planning habits, and students' opinion about potential features planned for software prototypes. The survey was conducted in June 2009 and targeted at all students in the School of Electronics and Computer Science (ECS) at the University of Southampton, which is also the intended target group for future research studies. ECS covers all disciplines in the fields electronics and computer science, and offers a whole range of undergraduate and postgraduate courses.

The survey itself is a questionnaire comprising 11 questions and divided into three parts (see Appendix A.1 for details), and students were expected to spend an average time of 10 minutes on answering it. Although no sensitive or personal data was gathered, the school's Ethics Committee approval was required before the start of the survey. In order to facilitate and speed up the process, the questionnaire was provided online on the school intranet, and students had to log on using their school username and password. This was to rule out that students answer the questionnaire twice, and that any other students who are not in the target group participate. However, this login data was kept separately from the questionnaire results, so that the survey was completely anonymous. In total, 137 out of around 1200 students answered the questionnaire, however, the online survey system used in the study did not enforce that students answer all questions, which resulted in 1 up to 13 missing values dependent on the question. The highest number of missing cases (between 10 and 13) occurred in question 9, which asked them to rate the degree of helpfulness of 13 features planned for the software prototype. It is likely that students lost interest or became distracted towards the end of the questionnaire, possibly because of the high number of items in that question. In the following analysis, missing values were not taken into account.

3.1 Results

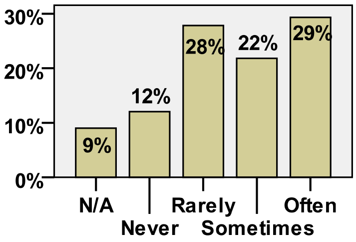
The first part of the questionnaire deals with devices available to students and their frequency of use. In this context, availability means that the device is either owned by the student or that they have unrestricted access to it. The results should indicate which technologies (for example location awareness) can be used in software prototypes, and what target devices should be supported. Student responses to these items are depicted in Figure 3.1.1.



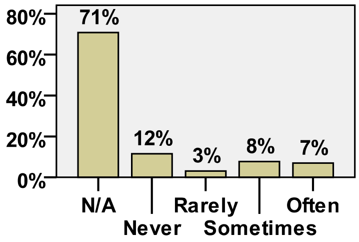
(a) PC/Mac (b) Laptop/Notebook (c) Netbook (d) Windows Smartphone/PDA (e) Apple iPhone (f) Apple iPod Touch (g) Android Phone (h) Other Touchphone (i) Other PDA (j) Other Mobile

Figure 3.1.1: Students' frequency of use of devices they own or have unrestricted access to

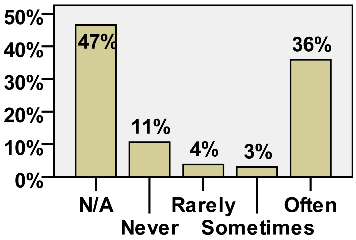
Most often used devices are personal computers or Macs, laptops, and mobile phones. Then, the questionnaire asked for the frequency at which students carry around any of these devices on campus; this is shown in Figure 3.1.2. The majority of respondents carry mobile phones often, followed by smartphones, touchphones, or PDAs. Results for laptop devices are mixed. It should be noted that at the University of Southampton, students have access to computer terminals located all over the campus, so that bringing their own laptop is not necessary.



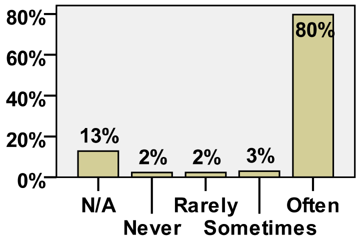
(a) Laptop/Notebook



(b) Netbook



(c) Smartphone, touchphone, or PDA



(d) Mobile phone

Figure 3.1.2: Frequency of student device use on campus

In the second case, when cumulating the results for devices carried on campus based on their technological features, yielding the categories mobile computers, mobile phones, and generally web-enabled devices, one gets the distribution shown in Figure 3.1.3. The result shows that nearly 76% of all students who participated in the survey have unrestricted access to and carry a web-enabled mobile device at least sometimes when they are on campus. This is equivalent to the third of a four-item scale ranging from "never" to "often". A mobile device in this context can be either a mobile computer (laptop/-notebook or netbook) or a smartphone capable of accessing the web and displaying web pages.

In the second part of the questionnaire, students were asked whether they pursued any time-management strategy, whether they made use of contemporary calendaring or project-management software, and how frequently they used such applications. The first two questions deal with calendaring software in general, that is, not specifically for study planning. Students were provided with a list of traditional calendaring software, such as Microsoft Outlook, Microsoft Calendar (Windows Vista only), Sunbird, and iCal (Mac), web-based calendaring systems, for instance Microsoft Outlook Web Access and Google Calendar, and mobile calendaring software as provided by their mobile or smartphone

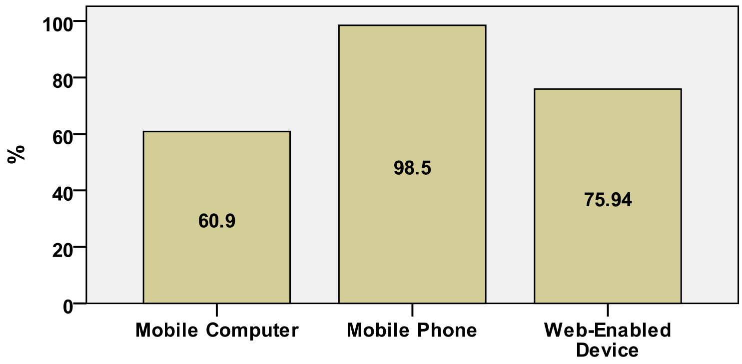
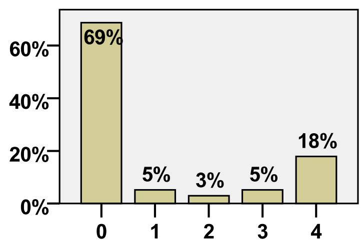
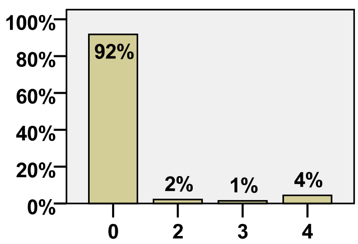


Figure 3.1.3: Devices carried on campus (at least sometimes)

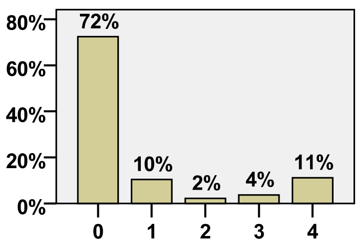
operating system. They were then asked to provide information about the frequency of use for each of these applications, chosen from a scale ranging from "never" to "daily".



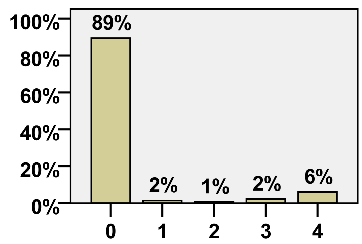
(a) Microsoft Outlook



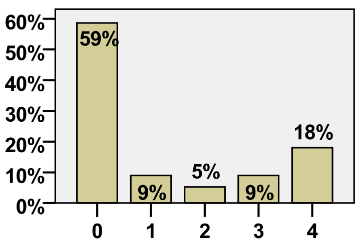
(b) Microsoft Calendar (on Windows Vista)



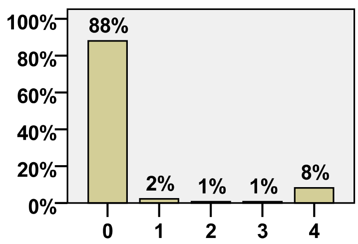
(c) Microsoft Outlook Web Access



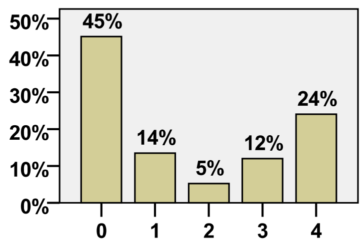
(d) Mozilla Sunbird



(e) Google Calendar



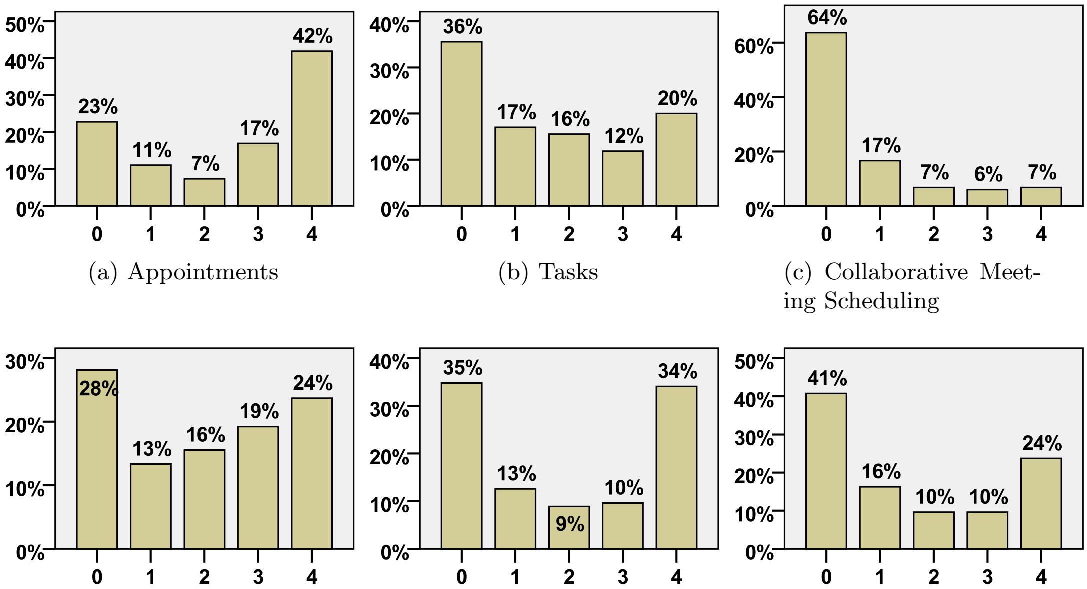
(f) Apple iCal



(g) Calendar on mobile phone

Figure 3.1.4: Use of calendaring software and its features, where 0 stands for "never", 1 for "once every couple of weeks", 2 for "once a week", 3 for "2-4 times a week", and 4 for "daily"

The bar charts in Figure 3.1.4 show the result, that is, the percentage of students using the corresponding application at different frequencies. They indicate that the majority of respondents use the calendaring software provided by their mobile or smartphone manufacturer, followed by Google Calendar and Microsoft Outlook. Unfortunately, some of the applications also provide communication features which are not specifically used for time management such as email and the results must hence be interpreted accordingly. However, this does not apply to the items Microsoft Calendar, Mozilla Sunbird, Google Calendar, and mobile calendaring software since these applications only provide calendaring features.



(a) Appointments (b) Tasks (c) Collaborative Meeting Scheduling

(d) Reminders (e) Contacts (f) Email for meeting organisation

Figure 3.1.5: Students' frequency of use of calendaring software features, where 0 stands for "never", 1 for "once every couple of weeks", 2 for "once a week", 3 for "2-4 times a week", and 4 for "daily"

Feature-wise, as shown in Figure 3.1.5, students use appointments more often than tasks and also make heavy use of reminders and contacts. Also, most students use conventional email communication to fix appointments for group meetings rather than utilising the special group meeting organisation features provided by Microsoft Outlook, for example. The reason might be that not all calendaring applications provide such a feature. These feature usage patterns correlate with the results of the next question (see Figure 3.1.6), which asked students to rate the helpfulness of the features, now in the context of personal study planning and time management. This indicates that those who generally use particular features also found them helpful or extremely helpful for planning their studies. Furthermore, students were asked to indicate which one of the above applications they use most for personal study planning (see Figure 3.1.7). 35.3% of students do not use any software to plan their studies, while those who do so prefer Google Calendar, Microsoft Outlook, and their mobile phone calendar with 15.4%, 14.7%, and 11.8%, respectively.

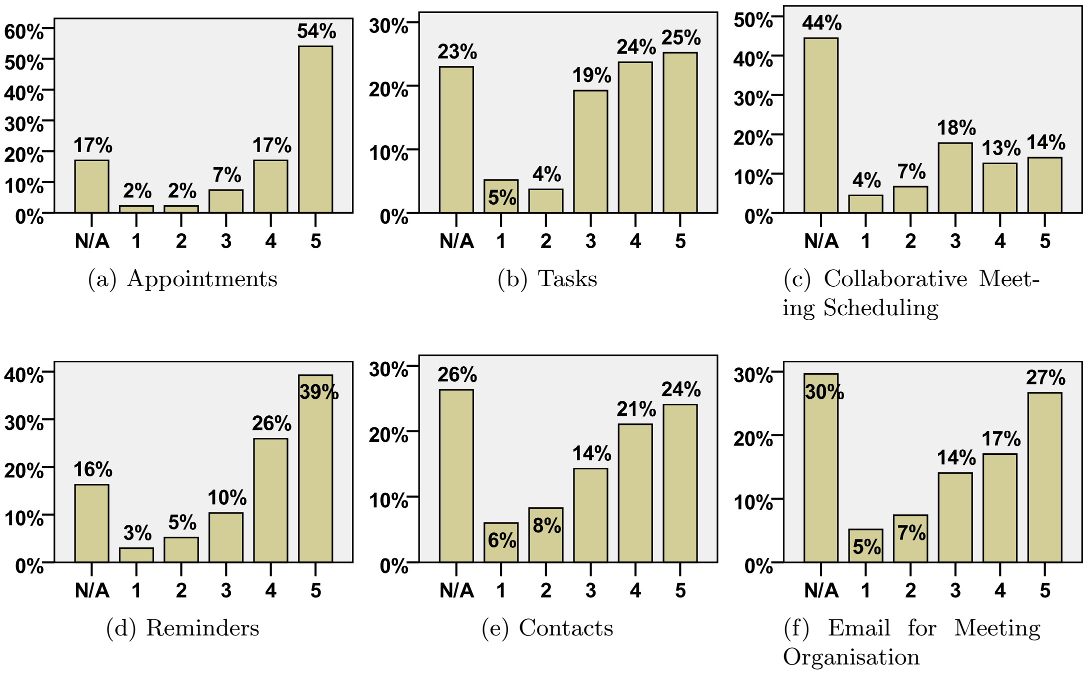


Figure 3.1.6: Helpfulness of calendaring software features for study planning, rated on a scale from 1 ("not at all helpful") to 5 ("extremely helpful")

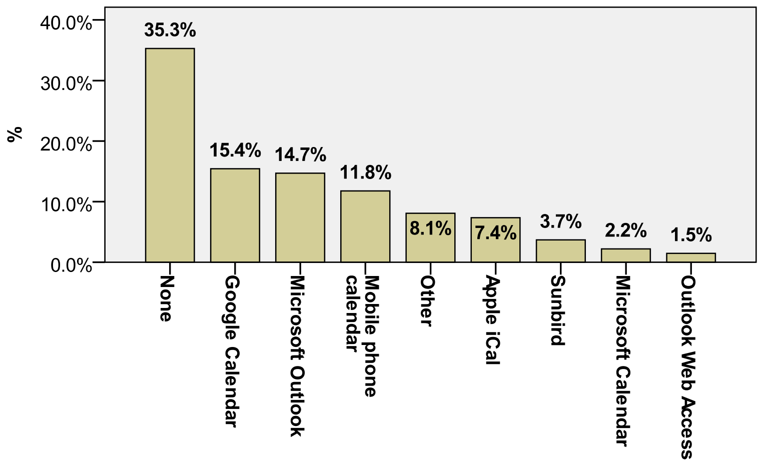


Figure 3.1.7: Calendaring software most used for study planning

Table 3.1: Categories for data analysis (question no. 8)

Category	Description
Technology ($j \in [1, 3]$)	
Pen & Paper	The student uses traditional pen & paper for managing their time
Software	A software application is used for time management purposes

Category	**Description**
No Tools	The student manages their time by keeping deadlines, tasks, and so on in their memory
Features ($j \in [4, 10]$)	
Diary	A paper or electronic diary is used
Calendar	A paper or electronic calendar is used
Log Book	A paper log book is used
Gantt Charts	The student draws Gantt charts on paper or by using software
Spread Sheets	Paper or electronic spreadsheets (for example Microsoft Excel) are used
To-Do Lists	The student keeps a paper or electronic list of tasks and subtasks
Timetable	A course timetable is used
Time Management Strategies ($j \in [11, 24]$)	
Deadlines	Exam and assignment deadlines are considered
Credits	When estimating the time on task, the number of marks achievable is taken into account
Task Size	When estimating the time on task, the (potential and individual) task size is considered
Subject	Time is managed based on the subject/module
Guessing	The time on task is guessed/estimated
FIFO	Tasks are performed in the order in which they were created
Prioritisation	Tasks are prioritised prior to performing them
Leave till End	Work on tasks is usually deferred until the deadline approaches
Fixed Working Times	The student indicated that they spend a fixed number of hours per day/week on study tasks
Plan	A weekly/monthly work plan is created and followed
Re-Adjustment	The plan or work schedule is regularly reviewed and adjusted
Sub-Tasking	Tasks are divided into smaller chunks (sub-tasks)
Strategy from Literature	The student indicated that they followed a particular time management strategy found in literature
Constant Work	The student works constantly, in other words, no designated revision/assignment periods are set
Other	
Synchronisation	The student uses software synchronisation techniques between different electronic devices

Category	**Description**
Multiple Calendars	There are several calendars based on context, for instance social activity calendar, study calendar, and others

The survey was also about the time management strategies students use, regardless of whether they involve using software or not. For one of the questions requiring a textual answer (question number 8) students had to provide details on such strategies, but since it required people to type in short texts, only 87 students, which is 63.5% of all participants, responded. For the purpose of data analysis, the answers were categorised based on the students' comments as shown in Table 3.1. There are 3 main categories, namely the technology, features, and time management strategies mentioned by students in their comments. These categories are divided into several items providing more concrete information. For each of these items, it was analysed whether students mentioned and used them, yielding a binary matrix A with each $a_{ij} \in [0, 1]$ where i denotes the case number (1 to 87) and j the category item in their answer; $a_{ij} = 1$ indicates that the ith participant mentioned the corresponding item j (see Table 3.1) in their answer, and $a_{ij} = 0$ the absence of that item. Of course the results obtained from this analysis are less accurate than those obtained from non-freetext questions because the comprehensiveness and detail of students' answers vary significantly. Consequently, students might still use a particular time management strategy, technology, or feature although they did not explicitly mention this. Furthermore, using the items in Table 3.1 and the calendaring software features shown in Figure 3.1.5, four different scores were created and used later for correlation analysis. The first three scores refer to the categories in Table 3.1: The technology score is defined as $S_T = \sum_{j=1}^{3} a_{ij}$, the feature score as $S_F = \sum_{j=4}^{10} a_{ij}$, and the strategy score $S_S = \sum_{j=11}^{24} a_{ij}$. The forth score is the software feature score $S_C = \sum_{j=1}^{6} c_{ij}$ with each j referring to one of the software features shown in Figure 3.1.5 and $c_{ij} \in [0, 4]$ being their frequency of use. The former three scores (S_T, S_F, and S_S) are negatively skewed with median 1 and interquartile range 0, 2, and 2, respectively, while the latter score (S_C) is normally distributed with mean 16.22 and $\sigma = 6.566$ ($p = 0.634$, Kolmogorov-Smirnov $Z = 0.746$).

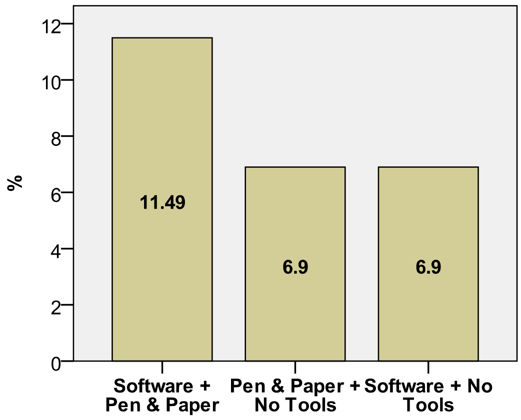
The results show that around 44% of all respondents use software for time management purposes, followed by traditional pen & paper (approximately 36%), while 30% do not use any particular technology. Furthermore, the most commonly used features are diaries/calendars, to-do lists, and timetables, whereas only few students use simple log books, spreadsheets, or Gantt charts (see Figure 3.1.8). The listed features are used in paper or electronic format, but in fact 10 students indicated that they use a mixture of both mediums.

With regard to time management strategies, one can distinguish simple from more sophisticated strategies. The simplest possible strategy is to guess the time on task solely based on its deadline. Combining this with other strategies such as consideration of task size, task priority, and the number of achievable credits/marks yields more sophisticated strategies. Table 3.2 shows a breakdown of the number of respondents who mentioned any possible combination of strategies in descending order. That is, the most frequent combinations are listed in the top left quarter of the table (shaded area), the least common combinations in the lower right quarter. Only one student indicated that they use a particular time management strategy found in literature, and another student admitted to leave all work till the very end. The most common combinations of time management technologies is shown in Figure 3.1.8a, while Figure 3.1.9 shows the distribution of time management strategies.

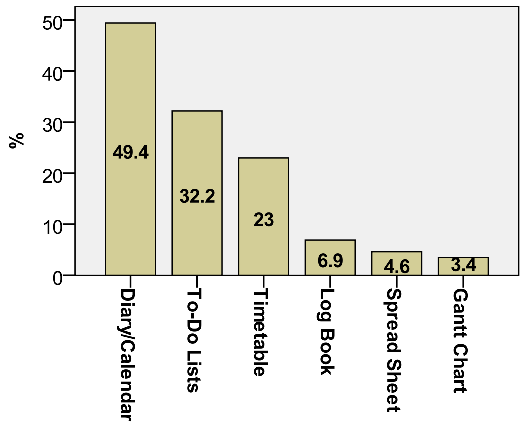
Table 3.2: Use of time management strategies; the shaded area shows the most frequent combinations

	Dead lines	Gues sing	Task Size	Priorit ising	Re-Adjust ment	Fixed Times (Daily)	Cred.	Subj.	FIFO	Sub-Tasking	Monthly Plan	Const. Work	Leave t. End	From Lit.
Deadlines	**56**	18	11	9	7	2	3	2	1	3	2	1	1	1
Guessing	18	**21**	9	6	5	2	1	3	0	1	2	0	0	0
Task Size	11	9	**11**	3	2	0	1	1	0	0	0	0	0	0
Prioritising	9	6	3	**10**	4	1	2	2	0	2	1	0	0	1
Re-Adjustment	7	5	2	4	**7**	1	0	0	0	2	1	0	0	1
Fixed Times (Daily)	2	2	0	1	1	**5**	0	1	0	0	0	0	0	0
Credits	3	1	1	2	0	0	**3**	0	0	0	0	0	0	0
Subject	2	3	1	2	0	1	0	**3**	0	0	0	0	0	0
FIFO	1	0	0	0	0	0	0	0	**3**	0	0	0	0	0
Sub-Tasking	3	1	0	2	2	0	0	0	0	**3**	0	0	0	1
Monthly Plan	2	2	0	1	1	0	0	0	0	0	**2**	0	0	0
Constant Work	1	0	0	0	0	0	0	0	0	0	0	**2**	0	0
Leave till End	1	0	0	0	0	0	0	0	0	0	0	0	**1**	0
From Literature	1	0	0	1	1	0	0	0	0	1	0	0	0	**1**

Furthermore, students were asked to assess their own time management skills by rating their agreement with 4 time management statements on a 5-point Likert scale. The statements are (1) "I consider myself a good time-manager", (2) "I often struggle to meet deadlines", (3) "I have missed deadlines in the past", and (4) "I can estimate the time I need for studying a subject or performing a task fairly accurately". In addition, students were asked whether they (5) think that contemporary calendaring software lacks features supporting learning and studying. The results for time management statements one to five are shown in Table 3.3;



(a) Technology combinations



(b) Features

Figure 3.1.8: Time management technology combinations and features used by students

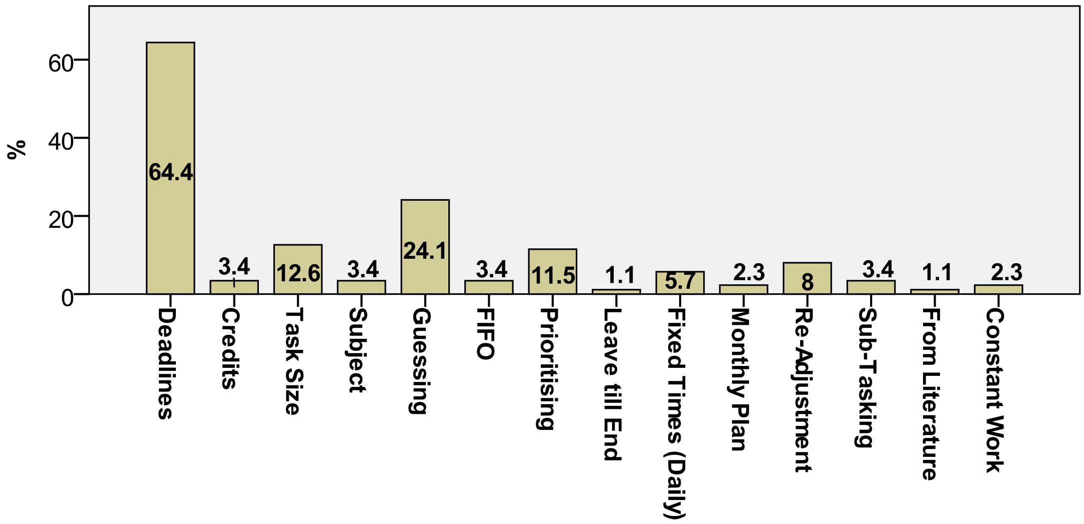


Figure 3.1.9: Time management strategies used by students

Table 3.3: Answers to time management statements 1 to 5 (highest percentage underlined)

Statement	Agreement (%)		
	No	Not Sure	Yes
1	13.3	25.2	<u>61.5</u>
2	<u>52.6</u>	21.5	25.9
3	<u>57.4</u>	8.1	34.6
4	22.4	33.6	<u>44.0</u>
5	20.1	<u>40.3</u>	39.6

all answers were recoded into a three-point scale {"No", "Not Sure", "Yes"} expressing the participant's agreement with the corresponding statement.

Finally, in the third and last part of the questionnaire, students rated the helpfulness of 13 software features using a 5-point Likert scale. These features cover aspects of traditional time management, enhanced social presence, and project-based learning. The results are shown in Table 3.4.

Table 3.4: Student organiser software features and their helpfulness (highest percentage underlined)

	Helpfulness (%)		
Feature	**Very Helpful**	**Helpful**	**Not Helpful**
Task/event synchronisation	74.3	12.5	13.3
Schedule meetings with supervisor	74.8	18.9	6.3
Schedule group meetings	76.3	14.2	9.4
Division of work in group assignments	58.3	26.8	15.0
Observing group/peer progress	58.7	24.6	16.7
Time-on-task estimation	57.5	18.9	23.6
Critical task warnings	77.0	15.1	8.0
Locating friends on a campus map	36.2	18.9	44.8
Finding subject experts	41.3	27.0	31.8
Location-based reminders	45.6	23.2	31.2
Finding learning resources	48.4	31.0	20.6
Geo-location and sharing of resources	38.7	29.8	31.5
Resource rating and annotation	48.0	30.4	19.7

Again, student answers were recoded from a 5-point Likert scale value into a three-point scale for simplicity reasons. Furthermore, 39.6% of all participants indicated that they would use timetabling information, and coursework hand-in deadlines provided by the university or school given that such data could be easily imported into existing calendaring software, while 40.3% were not sure and 20.1% said that they would not use such data.

3.2 Correlations

In the next step, the SPSS Statistics software package was used on the result data set in order to find correlations between variables. Possible variable types are [Connolly, 2007]:

Nominal Describes a defined set of (textual) categories whose order is not important. It does not make sense to calculate their means. Example: a person's nationality.

Ordinal Describes a defined set of categories expressed in words or a numerical range. Their order is important and relevant but it does not make sense to calculate their means. Example: Likert scale answer values.

Scale Describes a numerical value not referring to a category and which has an inherent meaning. Example: a person's age.

The following statistical tests were applied to test the relationship between these types of variable:

- Nominal × Nominal: Chi-Square (χ^2) test
- Nominal × Ordinal: Mann-Whitney U Test
- Ordinal × Ordinal and Ordinal × Scale: Spearman Correlation Test (correlation coefficient r_s, probability p)
- Scale × Scale: Pearson Correlation Test (correlation coefficient r, probability p)

Furthermore, the Kolmogorov-Smirnov test was used to determine whether scale variables are normally distributed or not.

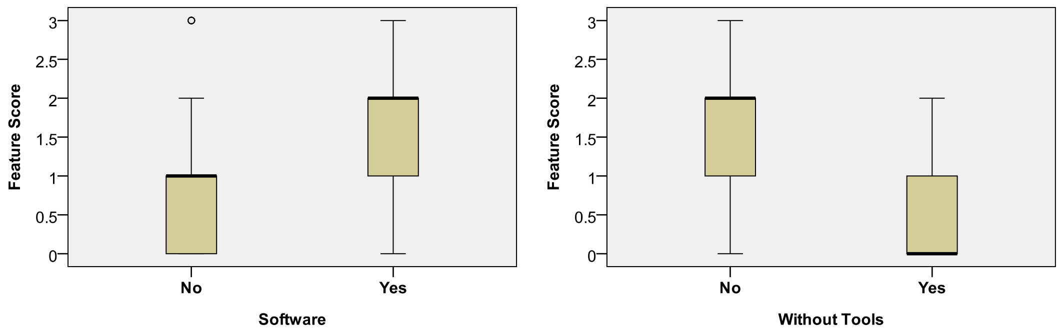
A positive and significant correlation ($p < 0.01$) was found between the frequency of use of calendaring application features and their helpfulness ranking, in other words, those features used more often were also perceived more helpful for study planning. The Spearman correlation coefficient r_s ranged from 0.511 to 0.712.

In view of time management statements, those who agreed with being good time managers indicated that they do not struggle to meet deadline and have not missed them in the past ($p < 0.01$) with $r_s = -0.528$ and -0.407, respectively. However, a positive correlation was found between agreement with good time management and good time estimation ($r_s = 0.388$, $p < 0.01$). Conversely, those who did not find that they are good in time management also found themselves struggling with deadlines ($r_s = -0.528$) and time estimation ($r_s = -0.309$). This correlation was significant at the 0.01 level. The same group of people also agreed with the statement that there is not enough software support for study time management ($r_s = 0.184$, $p < 0.05$). Comparing time management statements with the calendaring feature score S_C, measuring the number and frequency of calendaring software features used by participants, a positive correlation was found between S_C and statements 2 ($r_s = 0.185$, $p < 0.05$) and 3 ($r_s = 0.345$, $p < 0.01$), that is, those participants who struggle with deadlines or have missed them in the past use more calendaring features more frequently.

The analysis of the textual responses to time management strategies also yielded some interesting correlations. The Chi-Square test with a degree of freedom $df = 1$ was used here because matrix A only contains binary elements

$$a_{ij} = \begin{cases} 1 & \text{participant's answer contains item } j \\ 0 & \text{otherwise} \end{cases}$$

and is therefore regarded as a nominal variable. The technology "software" correlates positively and significantly ($p < 0.001$) with features "calendar" ($r_s = 0.443$, $\chi^2 = 17.08$) and "timetable" ($r_s = 0.345$, $\chi^2 = 10.357$). Furthermore, the Mann-Whitney U test showed a positive correlation with the overall feature score S_F ($r_s = 0.427$, $U = 478.0$, $Z = 4.042$, $r = 0.433$, $p = 0.000$), while a negative correlation was found with guessing as a way of time-on-task estimation ($r_s = -0.280$, $\chi^2 = 6.827$, $p = 0.009$, $df = 1$). In contrast, participants who indicated that they do not use any tools for time management also use fewer time management features, resulting in a lower feature score S_F ($r_s = -0.506$, $p = 0.000$, Mann-Whitney $U = 296.0$, $Z = 4.805$, $r = 0.515$). These two relationships with the feature score are also shown in Figure 3.2.1.



(a) Relationship between feature score and technology "software" with 3 outliers scoring 3.0

(b) Relationship between feature score and technology "no tools"

Figure 3.2.1: Relationship between feature score and technologies "software" and "no tools"

3.3 Discussion

One of the main findings of the survey is the high prevalence of mobile devices (all participants own at least one mobile device) and the frequent use of web-enabled mobile devices. Regarding the latter type of device, 96% of respondents indicated that they own such a device and 76% carry it on campus at least sometimes. These numbers are fairly high. One possible explanation is that such devices have become more affordable, powerful, and smaller, enabling the combination of an increasing number of features in one device. They could also be explained by the target group itself; it is likely that Computer Science and Electronics students are ahead in view of information technology use compared to students in other disciplines. A cross-disciplinary survey could shed more light on this issue. However, the high prevalence of web-enabled and connected devices could yield more complex and useful mobile learning applications and facilitate their adoption. Ideally, future applications will be more web-based and less platform-dependent while being more flexible at the same time.

With regard to calendaring software and their features, a very diverse use was found. This could be explained by time management being a very individual activity. However, more than half of all participants use calendaring software on their mobile device, for example, their mobile phone. This goes in line with the findings about mobile devices mentioned above. Also, Google Calendar was the second most-used calendaring applications, possibly because it is a web-based service providing suitable synchronisation tools for nearly every client calendaring system. For instance, data in online Google calendars can easily be synchronised to the iPhone, to Microsoft Pocket Outlook on a Windows Mobile smartphone, or to any other client software capable of importing iCal-files. Google Calendar is also the application which is used most for study planning. Surprisingly, only a very small proportion of respondents use Microsoft Outlook Web Access despite this being university standard software. At Southampton University, all student mail accounts are now hosted on Microsoft Exchange. Besides email, each Exchange account also provides a calendar, task list, and electronic notes. However, the current university policy does not allow client tools to connect and synchronise with a student Exchange account, which might explain the low uptake of Outlook Web Access.

Another surprising finding is the high proportion (61.5%) of respondents who claim to be good time managers. Unfortunately, students were not asked for their year of study in the online questionnaire, and although it is likely that more experienced students report better time management compared to freshmen [Trueman and Hartley, 1996], such a relationship could not be verified using the survey data. Therefore, is is also unknown whether the majority of participants were experienced students, which might have explained the high confidence in their time management skills. Furthermore, more research is needed to evaluate whether self-reported time management skills match with quantitative data. This could be achieved by analysing data of an electronic coursework hand-in system which is used in ECS at Southampton, and by comparing the degree to which hand-in deadlines are met with self-assessed time management behaviour.

In more detail, the study revealed that there is no significant relationship between time management proficiency, that is, self-reported time management skills, and use of calendaring software and their features. In other words, those who claim to be good time managers do not necessarily use more software and more features. Instead, the analysis of reported time management strategies showed that software is often used with other tools and mediums such as paper-based diaries. The study also revealed that most participants use deadline-driven and hence short-range time management behaviours. This finding supports the assumption made by Britton and Tesser [1991] that this behaviour is caused by the nature of the university education environment itself, because demands change more swiftly than in other environments, making short-range planning more important. Also, this finding is in contrast with that of Trueman and Hartley [1996], who report long-range planning to be more effective in terms of higher student performance.

Conversely, the two statements "struggle to meet deadlines" and "have missed deadlines in the past" correlate positively with the number of calendaring software features and their frequency of use. This might be explained by students attempting to compensate deficiencies in their personal time management. In addition, students strongly agreeing with the two statements indicated that contemporary calendaring software does not provide enough support for student learning. In other words, these students would like to see such software providing features specifically aimed at study planning. Furthermore, participants using software for study time management reported less use of guessing for time-on-task estimation. This might be on the grounds that using software facilitates the creation of time logs, enabling students to estimate the time-on-task based on similar tasks performed in the past, or that such software provides features for generating such times automatically.

Regarding the helpfulness of proposed study planner software features for study time management, 12 out of 13 features were rated very helpful (see Table 3.4). The feature "locating friends on a campus map" obviously made less sense to most students, maybe because it is – at the first glance – not related to time management.

In conclusion, the survey provided very valuable results in terms of devices, calendaring software, and their frequency of use. This data, in connection with feature helpfulness ratings, can also be helpful for the design of system prototypes. The analysis of time management strategies, provided as a textual response by participants, yielded less significant results. Generally, time management remains a very individual activity, supported by a wide range of devices, platforms, software tools, features, and practices. This also supports finding in related work [Blandford and Green, 2001].

Chapter 4

Using a Technology-Enhanced Study Planning Tool

The findings from the time management and technology survey described in the previous chapter lead to the following considerations regarding student time management and study planning:

Firstly, existing client software concerned with time management, such as Microsoft Outlook, Mozilla Sunbird, and others, despite allowing for individual study planning, lacks features enabling the coordination of collaborative learning activities, for instance in group assignments. Furthermore, it is designed for professional workplace environments rather than educational environments. The latter are less structured, more heterogeneous, and pose other challenges to their members. The survey results presented in Chapter 3, in particular the feature helpfulness rankings and the correlation between self-reported poor time management and lack of software features, reflect this issue.

Secondly, existing groupware software or any server-based calendaring software can alleviate the problem of heterogeneous client environments, however, these applications are typically generic and thus less specific. Again, the special requirements of educational contexts are not considered in such applications.

Thirdly, it appears that none of the existing solutions mentioned above meets the special requirements of student study planning in educational environments. In particular, none of the following are taken into account: social aspects of learning, such as the communication between peers performing similar learning activities, the physical proximity of students on a campus, allowing for spontaneous interactions and meetings, and motivational aspects which have been shown to positively affect study planning (see section 2.3).

This chapter will describe the design of a first experimental research study and system prototype which is aimed at incorporating social aspects of learning, enhanced social presence, and motivational aspects. These aspects have been identified as missing from mainstream calendaring software (see above) yet are beneficial to student time management and study planning. Although enhanced social presence is associated with locating peers on a campus map, and despite this feature not being perceived helpful by a majority of survey respondents, it is claimed that it can lead to spontaneous group formation and learner interaction, which may, in turn, instigate motivation [Eisenstadt and Dzbor, 2002; Bai, 2003]. For that reason, it was decided to include this feature in the system design.

Rather than prescribing a particular time management strategy, the prototype is an assembly of related tools which may be used for personal time management and study planning, while users can still make an individual choice as to which features they wish to use. This approach seems sensible in view of the survey results covered in sections 3.1 and 3.3, which show that students use a wide range of different strategies based on their personal needs and experiences. Key aspects considered in the prototype and experiment are:

1. **Traditional time management**: The software should enable its users to create and modify tasks, define task interdependencies, and break large tasks down into a hierarchy of sub-tasks. All sub-tasks count towards the completion of their parent task. Task interdependencies are defined as prerequisite tasks, in other words, a task can be dependent on the completion of other tasks. Besides tasks, single and recurring events can be created. Examples of events are lectures, workshops, tutorials, and so on. These features implement an ideal time management process compiled from recommendations in related work (see section 2.3 on page 43). This process is depicted in Figure 4.0.1. It is designed as a feedback loop whereby positive or negative feedback is given during study plan reflection. Successfully completed tasks mean positive feeback and can serve as a motivator to continue towards the final goal while incomplete tasks mean negative feedback.

2. **User collaboration and social networking**: In order to allow for the effective collaboration of users, the system provides organisational units defining collaboration boundaries (see section 2.4 on page 56). In this work, these units are called "groups", and each group can hold sub-groups enabling fine-grained control over such boundaries. A user's membership in a group enables their collaboration with other group members. Furthermore, task information can be enriched and extended by creating comments and notes, resulting in a higher social presence of the medium (see section 2.4 on page 56) and enabling workspace and progress awareness for collaborating users.

3. **Enhanced presence and context-awareness**: The prototype provides a virtual map of the campus. The user's current geographical position is either automatically detected or manually set and disclosed to associated users, that is, to all members of groups a user belongs to. The map also serves as the central access point for

communicative features such as instant and private messaging and can enable users to meet up and interact spontaneously based on their present state (see section 2.4 on page 56).

4. **User motivation**: Besides enhanced presence, which is also said to have a positive effect on user motivation [Eisenstadt and Dzbor, 2002; Bai, 2003], a technique presented in the context of project-based learning will be applied [Mochizuki et al., 2008]. Progress made on tasks defined in the context of a group is automatically published to all other members of the group, enabling users to compare their individual progress on the same or similar tasks with that of their peers. Mochizuki et al. [2008] have shown that this can enhance students' sense of a learning community, which in turn sparks motivation, and instigate learning in a distributed environment. Another positive effect is that such cues can lead to a more realistic assessment of individual progress and the effort necessary to complete a task.

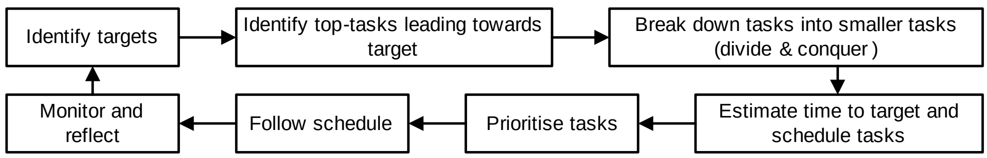


Figure 4.0.1: Ideal time management process (schematic overview)

In the context of the four technology-supported learning aspects (TSLAs) introduced in section 2.7 on page 68, prototype features are grouped so that each feature corresponds to one or more TSLAs as listed in Table 4.1.

Table 4.1: Technology-supported learning aspects and corresponding prototype features

Learning Aspect (TSLA)	Software Prototype Features
Motivation	Task progress statistics, virtual campus map (enhanced presence), group discussions
Time Management	Task list, event calendar, group discussions
Progress Awareness	Disclosure of task progress statistics
Monitoring	N/A

4.1 Hypotheses

The above aspects also define the primary objectives of the controlled experiment. They were used to derive four main atomic research hypotheses:

Hypothesis 4.1. Use of the web-based study planning environment increases student performance, defined as the average of all marks achieved by a student at the end of the academic term.

Hypothesis 4.2. Use of the web-based study planning environment decreases the number of late submissions on courseworks.

Hypothesis 4.3. Use of the web-based study planning environment increases perceived student motivation.

Hypothesis 4.4. Use of the web-based study planning environment decreases the student's perceived stress level.

It should be noted that due to insufficient user participation and the resulting lack of meaningful statistical data, these hypotheses could not tested in the context of this experiment. Instead, a similar follow-up experiment was conducted in the context of Master of Science summer projects, which is described in Chapters 5 and 6.

4.2 Research Methods

The first software prototype is used in an experiment involving students in the School of Electronics and Computer Science (ECS). The main research hypotheses of this experiment were introduced in the previous section. Students' academic performance in this context is defined as the marks gained by a student. Coursework submission behaviour is assessed by analysing the statistics of the school's coursework hand-in system C-BASS. Perceived student motivation and stress levels are subjective and students are expected to provide self-reports by filling in online questionnaires.

A controlled two-condition repeated measures experiment design was chosen [Field and Hole, 2006]. In the first instance, it involves only first-year students studying on an undergraduate degree in ECS. For this purpose, two modules, each from two different first-year undergraduate courses, were chosen and participants were recruited during a short introductory talk in the second week of semester 1, 2009. Also, several follow-up experiments with more experienced students and/or MSc/PhD students are planned based on the results of the first experiment and in order to analyse possible differences.

The two courses chosen for the first experiment are "BSc Computer Science" and "BSc Information Technology in Organisations" (ITO) with the first-year modules "Programming Principles" (COMP1004) and "Information Technology and Systems" (INFO1016), respectively. Assessment in both modules is very similar: 20 credit points can be gained and students are assessed through coursework, practical work (laboratory work or programming, for example), and examination. This ensures that a whole range of different task types are available and can be managed using the prototype software.

To test the research hypotheses previously mentioned, several data sources will be analysed:

- System log data: All student activity in the prototype system is logged. This includes data about features used, frequency of message exchanges through the platform, all task progress data, and any other user-system interaction.

- Performance data: the marks and C-BASS coursework hand-in statistics of each student participating in the trial.
- Questionnaire data: the results of all online questionnaires. Questions are mainly about motivational aspects, subjective feedback on the prototype, and time management behaviours applied outside the prototype environment.

Due to the nature of the above measurements and the experiment design, the school's ethics committee approval had to be sought before the experiment could begin, and a formal participant sign-up process was required. Consequently, each participant received an experiment information sheet and had to sign a consent sheet before they could be included in the trial (see Appendix B for details). Participation was completely voluntary and students were free to spend as much time as they wanted working with the prototype. Furthermore, no inducement was provided.

Then, for each module, participating students were randomly assigned to either trial or control group. This division is shown in Table 4.2.

		Trial			**Groups**	
Course	**Students**	**Total**	**Male**	**Female**	**Trial**	**Control**
Programming Principles	95	49 (51.5%)	42 (85.7%)	7 (14.3%)	24	25
IT and Systems	31	16 (51.6%)	11 (68.8%)	5 (31.2%)	8	8
Total	126	65	53	12	32	33

Table 4.2: Experiment participants

In her time management behaviour study, Macan [1990] found differences in time management proficiency between males and females. More specifically, she discovered that women seem to be better time managers than men. In contrast, the study of Trueman and Hartley [1996] did not find any relationship between gender and time management proficiency. However, in order not to unintentionally bias the experiment and maintain the gender balance in groups, the proportion of females in each group and for each module was ensured to be equal to the proportion of females in the total number of participants.

At the end of the second week (semester 1), system logins were created and emailed to all students in the trial group, together with a small system introduction. Furthermore, a workshop was held in each module at the beginning of the third week, aimed at supporting students in getting started with the system. However, student participation in both sessions was very low, that is, about 1% of the computer science and 5% of the ITO course participants attended. Students were also encouraged to contribute so that system information (task and event data) remains accurate and up-to-date.

The repeated measures component of the experiment is achieved by swapping groups after the first semester; in other words, students assigned to the trial group in semester 1 will be in the control group in semester 2. Similarly, students who are in the control group in semester 1 will constitute the trial group in semester 2.

4.3 Prototype

From the above aspects, a number of use cases were derived and modelled using UML (see Figures 4.3.1 and 4.3.2). Note that, for simplicity reasons, all features are assigned to either of two categories "collaboration" and "time management".

Figure 4.3.1: Collaboration use cases

Before the design and architecture of the prototype are described, definitions of some terms used throughout this section and a set of rules governing the prototype system behaviour will be introduced.

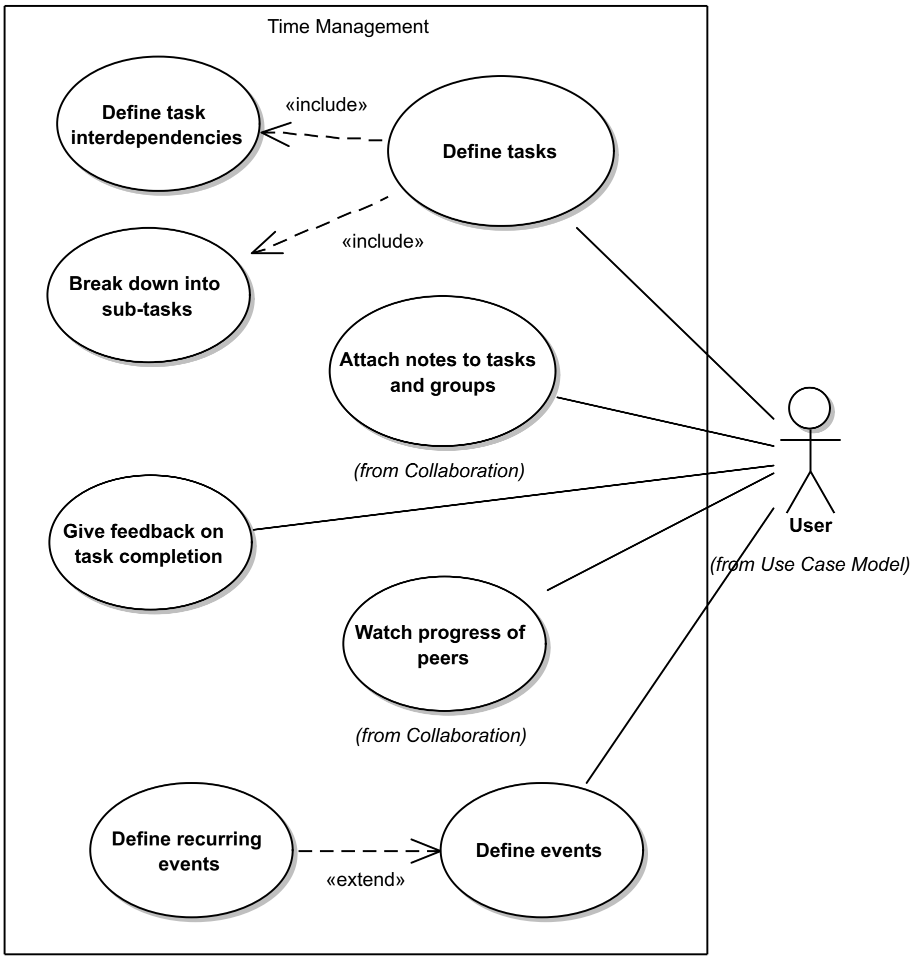


Figure 4.3.2: Time management use cases

Definition 4.1. The set of all *planning items* is defined as I and contains all tasks s_i and events e_i with $i \in \{1, 2, \ldots, n\}$ defined in the scope of the system, such that $\{s_1, s_2, \ldots, s_n\} \subsetneq I$ and $\{e_1, e_2, \ldots, e_n\} \subsetneq I$.

Definition 4.2. A *task* is an ten-tuple $s = (t_d, d_p, d_a, p, l_s, o_s, U_s, c, P, s_s)$ with t_d being the date and time when the task is due, d_p the planned task duration (time-on-task) in hours, d_a the actual task duration in hours, p the current percentage of task completion with $p \in \mathbb{R}$ and $0 \leq p \leq 100$, l_s the location where the task is to be performed, o_s the task owner, and U_s a set of users collaborating on this task. The task complexity c is defined as $c \in \{1, 2, 3\}$ with 1 denoting low, 2 medium, and 3 high complexity. Moreover, let t_n be the current date and time, then the *task state* is a function yielding a colour code, such that

$$q(s) = \begin{cases} \text{red} & t_d - d_p - t_n \leq 0 \\ \text{yellow} & 0 < t_d - d_p - t_n \leq 3 \text{ days} \\ \text{green} & t_d - d_p - t_n > 3 \text{ days} \end{cases}$$

The task owner o_s can be either a group or a particular user and specifies the task's visibility. The type of owner, that is, either group or user, is defined as $y(o_s) \in \{\text{Group}, \text{User}\}$.

In the former case the task is called a *group task*, and in the latter case the task is called an *individual task.*

In addition, tasks can have a semantic type $z(s) \in \{\text{Individual}, \text{Collaborative}, \text{Template}\}$ with the following constraints:

$$z(s) = \text{Individual} \Leftrightarrow y(o_s) = \text{User} \wedge |U_s| = 1 \tag{4.3.1}$$

$$z(s) = \text{Collaborative} \Leftrightarrow y(o_s) = \text{User} \wedge |U_s| \geq 1 \tag{4.3.2}$$

$$z(s) = \text{Template} \Leftrightarrow y(o_s) = \text{Group} \wedge |U_s| = 1 \tag{4.3.3}$$

A *task template* denotes a task which is defined in a group but must be worked on individually by each group member, such as an individual assignment. As its name suggests, it is used as a template for individual tasks generated for each member of the group o. Moreover, tasks can be nested such that there is a sub-tuple $s_s = (s_1, s_2, \ldots, s_n)$ with $s_i \neq s$ and $z(s) \in \{\text{Collaborative}, \text{Individual}\}$, provided that the following constraints are met:

$$z(s) = \text{Collaborative} \implies \forall s_i \in s_s \, (z(s_i) = \text{Collaborative}) \wedge U_s \subseteq M_u \tag{4.3.4}$$

$$z(s) = \text{Individual} \implies \forall s_i \in s_s \, (z(s_i) = \text{Individual}) \tag{4.3.5}$$

In Equation 4.3.4 above, M_u denotes the set of group members (see Definition 4.8 for details). For each task s, a set of *prerequisite* tasks $P = \{s_1, s_2, \ldots, s_n\}$ with $\forall s_i \in P \, (s_i \neq s)$ can be defined. All tasks $s_i \in P$ must be completed before work on s may begin, such that $\exists s_i \in P \, (r(s_i) < 100) \Rightarrow r(s) = 0$. Here, $r(s)$ defines the task progress described in the next definition.

Definition 4.3. The *progress* of a task is defined as a function

$$r(s) = \begin{cases} p & s_s = \emptyset \\ \frac{\sum_{i=1}^{n} r(s_i)}{n} & s_s = (s_1, s_2, \ldots, s_n) \end{cases}$$

If the task contains sub-tasks, its progress is the cumulated progress of its sub-tasks. Conversely, if the task does not contain any sub-tasks, the progress is simply its percentage of completion.

Definition 4.4. An *event* is defined as $e = (t_1, t_2, l_e, R, o_e)$ with t_1 being the start and t_2 the end date and time, l_e the location where the event takes place, and R an optional event recurrence pattern. Again, o_e denotes the event owner, which can be either a group or a specific user.

Definition 4.5. A *location* is a pair $l = (a_{\text{lat}}, a_{\text{lon}})$, whereby a_{lat} denotes the latitude of the location's geographical position and a_{lon} its longitude.

Definition 4.6. A *user* is a tuple $u = (l_u, C, M_u)$ with l_u being their current geographical location (see Definition 4.5) and C a set of traits characterising the user. M_u represents the set of groups g_i (see Definition 4.7) user u is member of, subject to the constraint $|M_u| \geq 1$. The first element of M_u is called the user's *base group*.

Definition 4.7. A *group* is a tuple $g = (M_g, o_g, s_g)$ where M_g represents the set of its members (users) and o_g the optional group owner, which must be a user u. Groups can be nested such that they contain tuples $s_g = (g_1, g_2, \ldots, g_n)$. A user's membership in a sub-group implies their membership in its parent group, such that $\forall g_i \in s_g \,(u \in M_{g_i} \implies u \in M_g)$. A group can have either of two types $z(g) \in \{\text{Private}, \text{Public}\}$. A private group is managed by its owner o_g, while a public group is managed by all its members.

Definition 4.8. *Group memberships* are given as a set $M = \{m_1, m_2, \ldots, m_n\}$ with each m_i being a tuple such that $m_i = (u_j, g_k)$ with $j, k \in \mathbb{N}^+$. In other words, each m_i associates a user u_j with an existing group g_k. The set of memberships with regard to a group g is M_g, and the membership with regard to a user u is given as M_u (see Definitions 4.6 and 4.7, respectively).

4.3.1 Design

Logically, the prototype software is divided into three main parts, namely the user model, the planner, and the enhanced social presence component. This logical architecture is shown in Figure 4.3.3. The central component here is the planner serving as a central access point to tasks and events. The planner retrieves the current user context from the model of the current user and that of all associated users. The user context is merely a set of user characteristics from the user model, such as their name, profile picture, contact data, and current geographical position. The enhanced presence component displays this information and all location-bound planning items on a virtual map which defines the boundaries of the user presence visualisation. It also enables the communication of all associated and connected users and can extend the user context by using data gathered during user-system interaction.

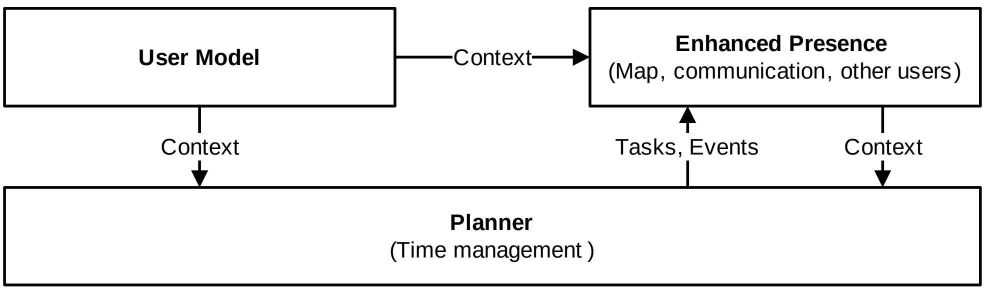


Figure 4.3.3: Logical system components

The technical system architecture is derived from the logical architecture above and depicted in Figure 4.3.4. It shows the packages and components serving as a container for all domain classes. The *flow* stereotype used in the figure denotes data objects being exchanged between packages or components. These can be tasks, events, or simply data entered by the user. The structural design of the user model component follows the rules given in Definitions 4.6, 4.7, and 4.5 in section 4.3. The result is shown in Figure 4.3.5. Classes `User` and `Group` both derive from an abstract superclass `Actor` which contains all common attributes and functionality. Similarly, user contact data is implemented as special classes deriving from the abstract class `Contact`. The system is designed to record the last ten geographical user positions, and each position is stored as an object of type `PositionHistoryEntry`. This class contains the position latitude and longitude as well as the time when the position was set. A user's group membership is realised as a separate class `Membership`, whereby each object is characterised by its membership role which can be either "Member" or "Owner". Thus, a membership with role "Owner" replaces o in Definition 4.7.

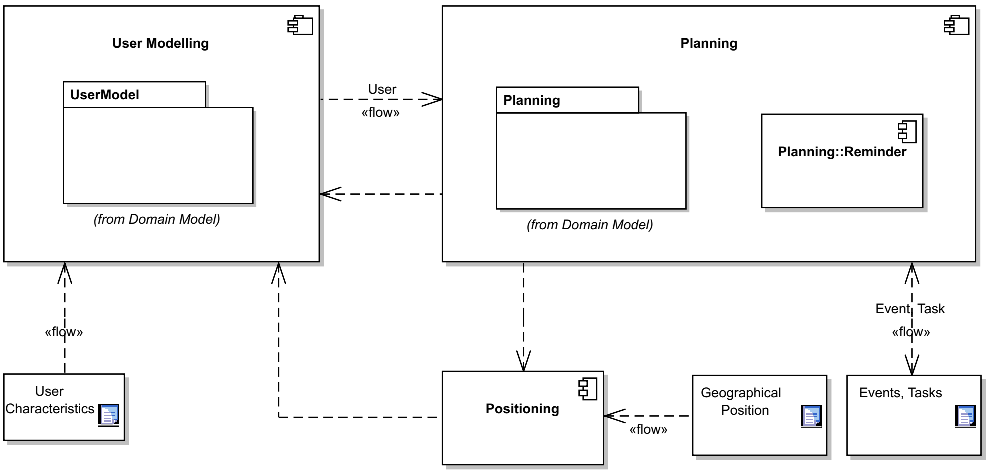


Figure 4.3.4: Technical system architecture

Similarly, the planning module is a realisation of Definitions 4.1, 4.4, 4.2, and 4.3. Its structure is shown in Figure 4.3.6. As described in Definition 4.1, there are two types of planning item, that is, either task or event. Tasks can be divided further into individual tasks (class `IndividualTask`) which are only visible to the user who created them, and group tasks (abstract class `GroupTask`). The former type is associated with exactly one user, the latter type with exactly one group. All members in the group can access and modify group tasks. Again, there are two types of group task, namely collaborative tasks (class `CollaborativeTask`) and task templates (class `IndividualGroupTask`). Collaborative tasks are associated with a set of collaborating users, whereby these users must be members of the group in which the task is defined, following Equation 4.3.4 in Definition 4.2. Task templates are designed such that each member of the group works on their own individual task copy, in other words, there is one copy per group member and each copy is associated with the template. This ensures that progress data submitted

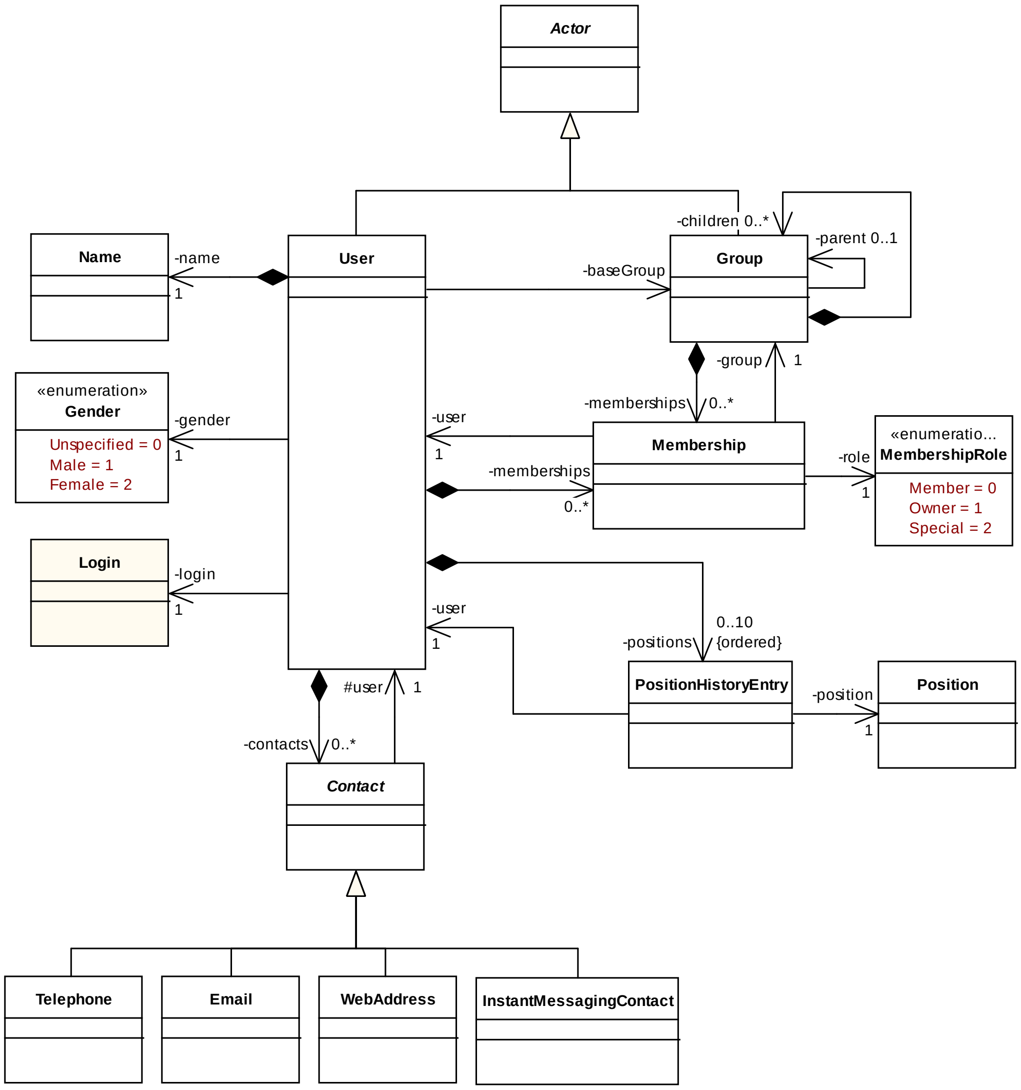


Figure 4.3.5: User model class diagram

on one of the copies is still related to its group task template. At the same time, each group member can modify data of their individual group task copy as they wish without affecting the template data. This also enables users to customise and break down the task into sub-tasks. In particular, individual members are able to modify the copy's due date, for example, in cases where an assignment extension has been granted. A user's progress on a task (class `ProgressNote`) can be submitted for tasks implementing the `IProgressableTask` interface and provided they do not contain any sub-tasks. More specifically, progress can only be made on individual and collaborative tasks, but not on task templates since they only serve as templates for individual tasks created for each group member. Along with the percentage of task completion and user effort, which is the number of hours spent working on the task, users can also enter small textual notes. Moreover, the task state at the time of progress submission is recorded.

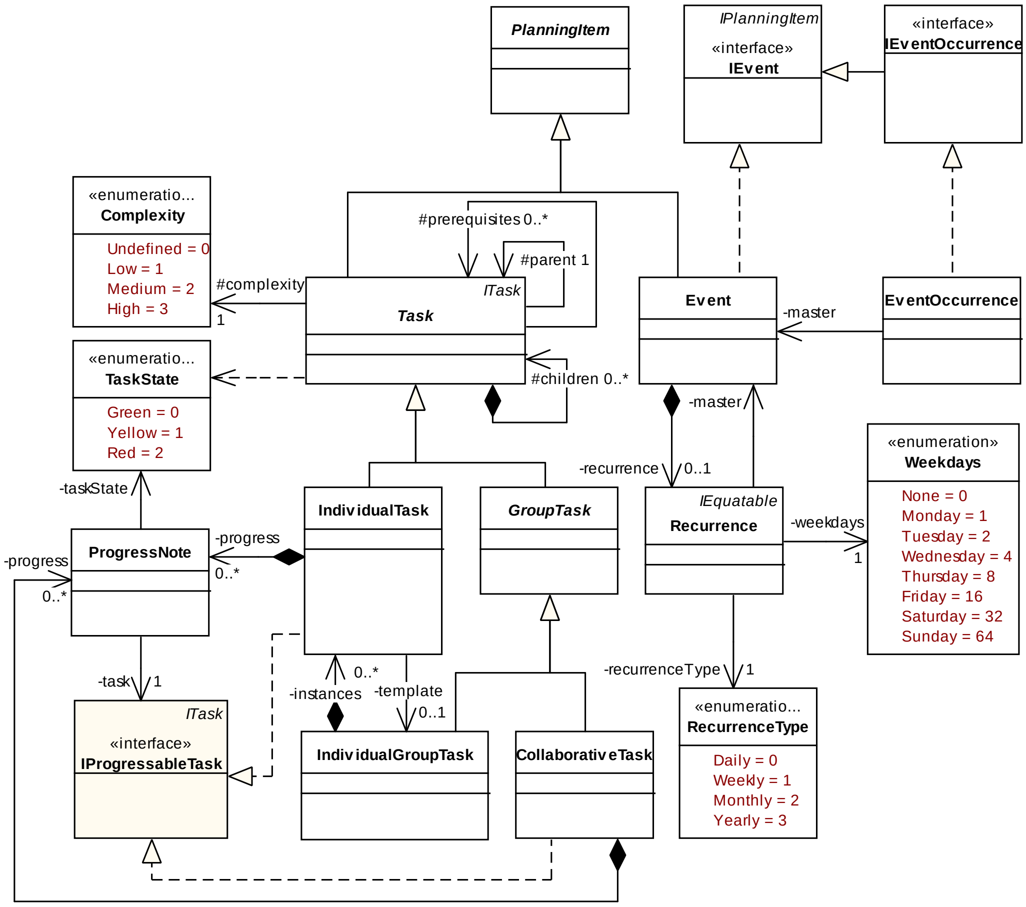


Figure 4.3.6: Planning class diagram

The social presence component (see Figure 4.3.3) is not entirely represented in the technical design. This is on the grounds that all data shown on the virtual map is retrieved from the user model and/or the planning module. However, social interactions between system users are provided in four ways. Firstly, users can communicate indirectly, that is, outside of the system boundaries, by using email; the user's email address is shown on the map and on their user profile. Secondly, users can use online messaging provided by the system as depicted in Figure 4.3.7. A new message (class `TextMessage`) automatically starts a new conversation (class `Conversation`). All replies to that message or any follow-up messages are attached to the existing conversation so that the message is set into a context. Furthermore, a conversation takes place between 2 or more users, including the user who started it. Once a message is read by a user, a new `TextMessageReadConfirmation` object is attached to the message. Thirdly, users can interact by using instant messaging (chat). For this purpose, an external third-party application is used. Fourthly and finally, social interaction can take place indirectly and asynchronously by enabling groups and planning items (tasks, events) to be annotated (see Figure 4.3.7). This is achieved by providing an abstract class `Note` and two specialised classes `GroupNote` and `PlanningItemNote`, associated with a group and a planning item, respectively. Notes are visible to all users who can access the associated group or planning item.

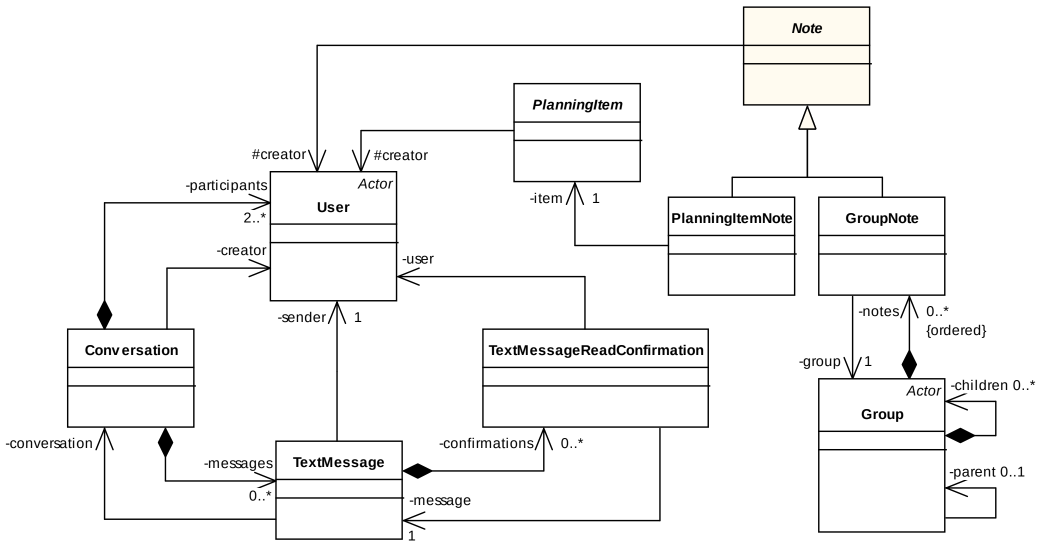


Figure 4.3.7: Social interaction class diagram

Groups, group tasks, and conversations also create something called an *event space*. Activities performed inside of an event space are propagated to all members of the group. For example, modifying the properties of a group will inform all other group members of that change. Similarly, when progress is submitted on a group task or any of its sub-tasks, this information is disclosed to all other group members. However, in this particular case, they will not be able to see the textual note attached to such progress reports.

4.3.2 Implementation

To ensure the software's maintainability and component re-usability, the technical implementation follows a three-layer architecture with the data layer at the bottom, the business logic in the middle, and the user interface at the top (see Figure 4.3.8).

In order to further decouple the layers from one another, a contract-driven software design was used. In other words, the communication between layers is service-based and governed by interface methods. More specifically, a separate service layer is placed on top of each of the three layers (data, business logic, and user interface), and each of these service layers exposes a set of interfaces defining the contract.

Here, the term *layer*s refers to logical components in the sense that they are not necessarily physically distributed, otherwise they are referred to as *tiers*. However, the separate service layer, which is only accessible through interfaces, also allows each logical layer to be deployed to a different physical device. Therefore, the software is designed such

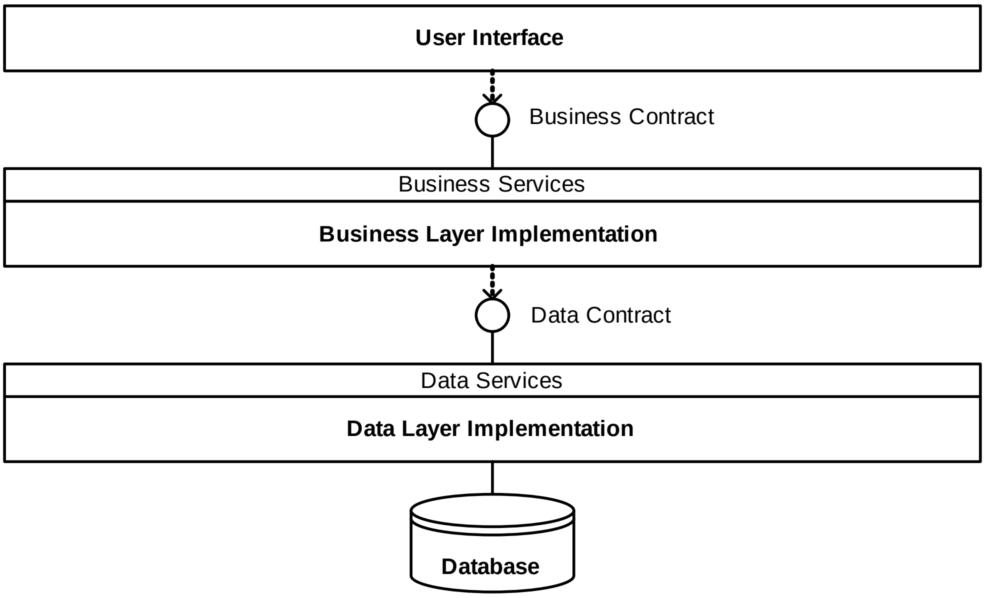


Figure 4.3.8: Three-layer software architecture

that each layer can become a tier and vice versa, allowing a high degree of flexibility and scalability.

For this design to be effective, *object factories* are used on the service layers [Gamma et al., 1995; Fowler, 2002]. This means that the interfaces which govern the inter-layer communication are mapped against a concrete interface implementation, that is, a class (and its assembly) realising that interface. This mapping is configured externally and can be modified without having to re-compile the program. For example, when the business layer needs to retrieve data from the data layer, it requests a data service instance from the object factory by using a particular data contract interface. The object factory loads all existing interface mappings from the external configuration and verifies that a mapping for the given interface exists. If this is the case, the factory creates a new instance of the mapped service class implementing the interface and returns it to the caller. Once created, the concrete service implementation instance can be held in memory for performance reasons. Subsequent requests for the same interface type will then result in the cached instance being returned.

4.3.2.1 Development Process

Sparx Enterprise Architect[1] (EA) was used for modelling use cases, components, and classes. Enterprise Architect can then generate the class source code, supporting a large range of programming languages. As opposed to many other case tools, code generation must be triggered manually and does not happen on-the-fly. This loose coupling

[1]http://www.sparxsystems.com.au

between model and code allows for greater flexibility while still providing all the benefits of model-driven development (MDD). The object-oriented development process went about iteratively following these steps:

1. Use case modelling: synthesising the software requirements yielding the use cases shown in Figures 4.3.1 and 4.3.2.
2. Software design: creating the structural and behavioural elements for each use case. These elements translate directly into code.
3. Database design: mapping object-oriented structures to the database.
4. Programming: implementing the functionality and functional requirements.
5. Testing: using automated unit tests and testing system functionality directly through the user interface.
6. Deployment and platform-specific tests.

During the process, a versioning system (Subversion[2]) was used to keep track of changes, to be able to return to any development state at any time, and to handle branches.

4.3.2.2 Technologies

After careful deliberation, the technologies shown in Table 4.3 were chosen for each layer shown in Figure 4.3.8.

Layer	Technology
User Interface	Microsoft ASP.NET 3.5 with AJAX.NET in combination with the AJAX Control Toolkit
Business Layer	Microsoft .NET 3.5 class libraries
Data Layer	Microsoft .NET 3.5 class libraries in combination with NHibernate 2.1.0 as a persistence framework
Data Store	Microsoft SQL Server 2008

Table 4.3: Technologies used in the prototype

Each layer is implemented as one or more assemblies, while the contract interfaces for both business and data service layer are held in separate assemblies. Other layers which are dependent on any of these two layers, for example the user interface, reference the service contract layer assembly containing the interfaces, not the concrete service implementation.

[2] http://subversion.tigris.org

The whole solution is operating on a Windows Server 2008 Enterprise Edition, using IIS as a web server, and hosted on a virtual machine provided locally by the school.

On the client side, only a browser supporting JavaScript is required. In this context, Microsoft Bing Maps[3] is used in combination with the Skyhook Wireless Loki API[4] to implement all enhanced presence features. The latter technology uses the signal and signature of wireless network access points in the area in order to determine the user's current geographical position. The positioning accuracy is dependent on the number of available WiFi hotspots, their signal strength, and the availability of locational information for each access point signature in the central database. Therefore, it can vary significantly. For this technology to work, an installed and enabled WiFi adaptor is required on the client device, although the adaptor does not have to be connected to a network. Because of possible position inaccuracies and because not all user devices come with a WiFi card, the software allows the user to manually set their position on the virtual map. Moreover, a web-based version of Microsoft Live Messenger[5] is used to realise the chat functionality mentioned in section 4.3.1.

4.3.2.3 Functionality

Now, let's delve into the implementation of the features touched on in section 4.3, seen from a user's perspective. First, however, here are some general user interface layout considerations.

The user interface is designed such that there is a consistent layout for all pages, a schematic overview of which is given in Figure 4.3.9. The layout comprises four *content areas*, namely (1) the navigation, (2) the content specific to the category chosen in the navigation, (3) the virtual map, and (4) the news feed. The latter two areas are sometimes occupied by alternative content. For example, when viewing task details, the current task context navigation, that is, its relative position in the task structure and the group it is defined in, and the task statistics are shown in this area. The navigation contains links to the main page, to the user profile page, to the list of tasks, events, and groups, to public and private locations, to the messaging page, and to the chat feature. Examples of the virtual map and news feed are depicted in Figures 4.3.10a and 4.3.10b, respectively. Most of the above entities (tasks, events, groups, locations, and messages) can be shown in either of two modes: the list mode provides a coarse-grained and paged overview, while the details mode provides a fine-grained overview.

Time Management The system provides two types of task list. Firstly, the structured task list view shows all tasks grouped by their prerequisite state. Following Definition 4.2 on page 93, a task can be in one of three prerequisite states at a time:

[3]http://www.bing.com/maps
[4]http://www.loki.com
[5]http://home.live.com/

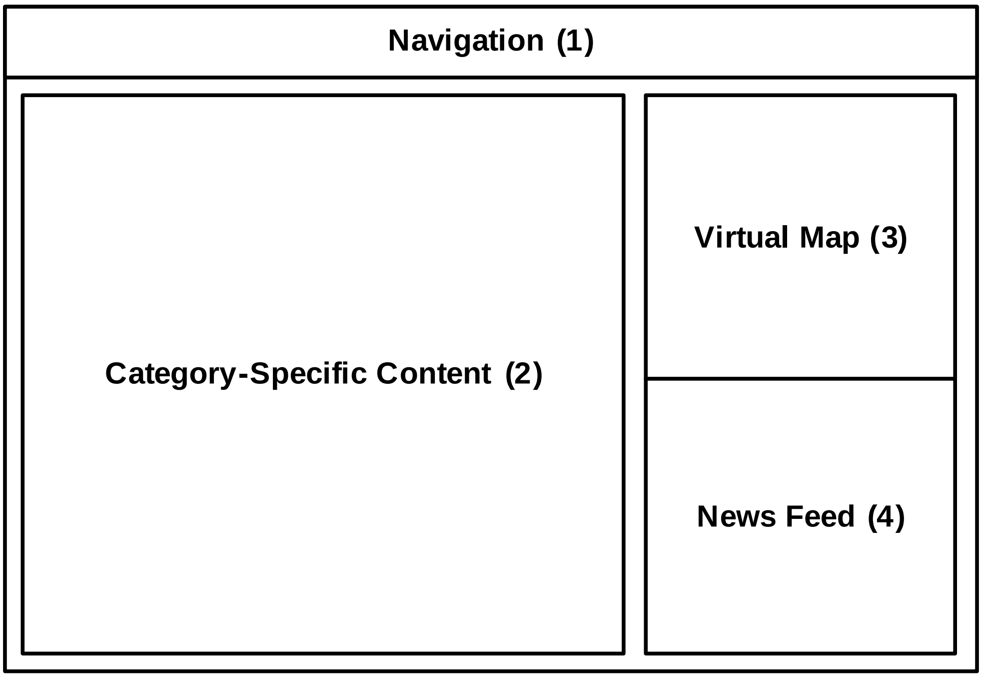
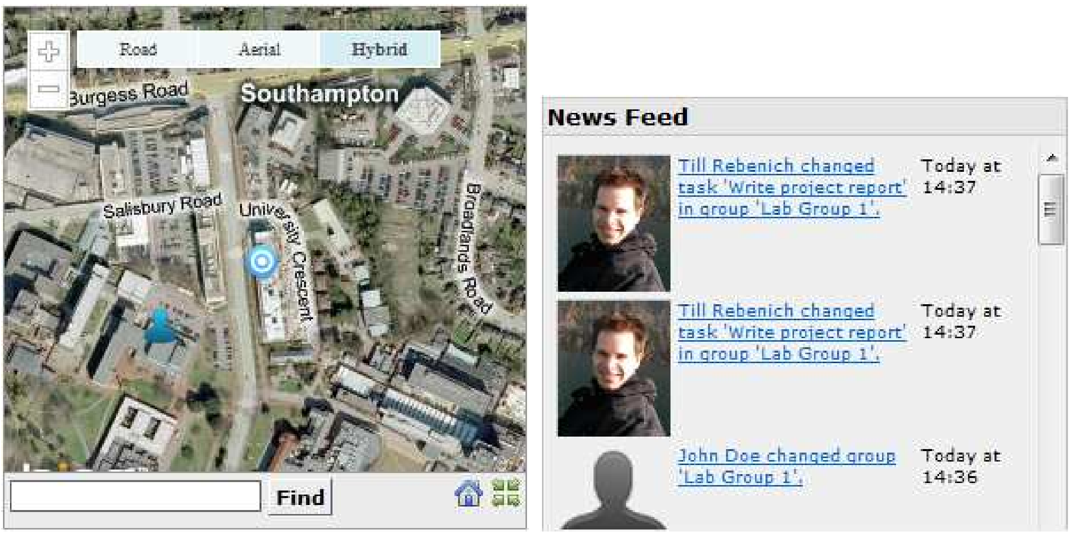


Figure 4.3.9: Schematic user interface layout



(a) Virtual map showing the location of the current user (blue circle) and another associated user (blue buddy icon)

(b) News feed

Figure 4.3.10: Screenshots of the virtual map and news feed

1. $P = \emptyset$, that is, the task does not have any prerequisites.

2. $P \neq \emptyset \wedge \forall s_i \in P\,(r(s_i) = 100)$, that is, the task has prerequisites and all of them are met.

3. $P \neq \emptyset \wedge \exists s_i \in P\,(r(s_i) < 100)$, that is, the task has prerequisites but at least one of them is not yet met. This is equivalent with any of the prerequisite tasks not

being 100% complete.

The first two states enable users to start working on the task immediately, while the third state means they have to complete any of the prerequisite tasks first. Consequently, the structured task list view contains three groups referring to each of the three states above and in that order. Within the three groups, tasks are ordered by their criticality $q(s)$ which is the task state as outlined in Definition 4.2 on page 93. The task list contains only tasks on the lowest level, that is, tasks which do not contain any sub-tasks. That is, let the task view be V_s and $s_s(s)$ denote the sub-tasks of s, then $\forall s_i \in V_s \left(s_s(s_i) = \emptyset\right)$ should hold.

A click on a task in the task list view takes users directly to the task details. Content area 2 (see Figure 4.3.9) of this page contains all task attributes, mainly its type, title, description, due date, planned duration, criticality, and the current user's progress in percent. If the task is derived from a group task template, the average progress of all members in the same group is also shown. Furthermore, there is an indicator showing whether the current user's progress is greater or less than the average member progress. Content area 3 shows information about the task's context. If the task is defined in a group, a link to that group and its title are provided. Furthermore, it contains a graphical tree showing the position of the currently active task in the structured task hierarchy. Finally, content area 4 contains useful statistics with regard to the current task (see Figure 4.3.11), provided that it is defined in a group. In more detail, the statistics panel shows:

- The number of group members (users) who have started on the task. If the group task is a template, this is defined as the number of users whose task copy completion rate is greater than zero percent, otherwise, if the group task is collaborative, as the number of collaborating users who have already made a contribution greater than zero percent.
- The number of group members who have completed the task. Again, in case of a task template instance, this is the number of users whose task copy completion is 100%. This metric is not provided for collaborative tasks.
- A list of users and their task effort and average contribution with regard to the group task. This list also shows the date and time when each user last submitted their progress.

The task details page can also be used to modify or delete the task, submit progress, or make personal annotations. Modifying a group task template instance results in the user's individual copy being modified, not the task template itself. There are no constraints whatsoever as for what task information can be changed.

Events are dealt with in a very similar way. There is a context-dependent event list view which shows the list of events defined in a group or for a particular user, and an event

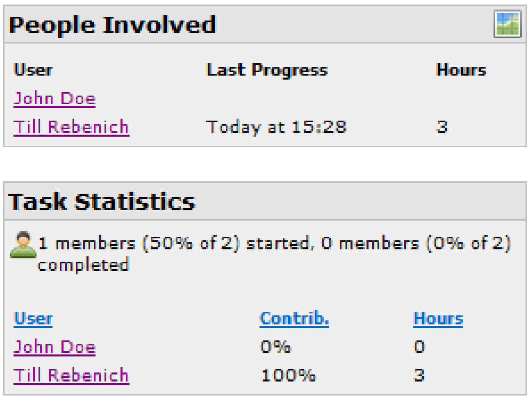


Figure 4.3.11: Group task statistics showing other group members and their contribution relative to the task progress

details view showing event data and allowing users to modify these. The system also supports recurring events and users can export existing task deadlines and events to an iCalendar[6] file. There are two ways to use this file. Firstly, users can download and import it into their calendaring client software, and secondly, users of Google Calendar[7] can use a persistent URL to that file and have its content indexed in regular intervals. Google Calendar then automatically updates the user's online calendar based on the indexed data.

User Collaboration and Social Networking The central actor in the system is the user. They must log on using their username and password, and can create their personal profile by uploading a profile picture, providing additional data as their gender, date of birth, and contact data. Additional information characterising a user is the set of groups they are member of, their current geographical location, and the set of tasks they are currently working on.

Groups are implemented as a hierarchical tree. Each group can contain an unlimited number of sub-groups and have one or zero parent groups. Those groups not referring to any parent groups are called *roots* and appear on the top-most hierarchical level of the tree. On the groups page, there are three sections embedded into content area 2. The first section contains a simple group search, the second section a list of the user's existing group memberships, and the third section the group tree mentioned above. A group membership is characterised by its type, which can be either "owner" or "member". Currently, the group owner is the user who created the group in the system. Their rights with regard to the group are determined by the group type. In private groups, the group owner is in charge of accepting new member requests and manages all group tasks and events. Consequently, users requesting membership of a private group must wait for its owner's acknowledgement. Conversely, public groups are open to everybody, and no special constraints are imposed on their members. This means that all members can

[6] iCalendar is a calendaring and scheduling file format created by the Internet Engineering Task Force
[7] http://calendar.google.com

modify any group content without the owner's consent. Typically, groups representing courses or course modules are implemented as public groups.

Users can communicate in three ways: (1) by emailing other users using the email address(es) provided on their profile, (2) by using the system's internal messaging system, and (3) by starting an instant messaging conversation using the online messenger feature provided. The system's internal and conversation-based messaging system is shown in Figure 4.3.12.

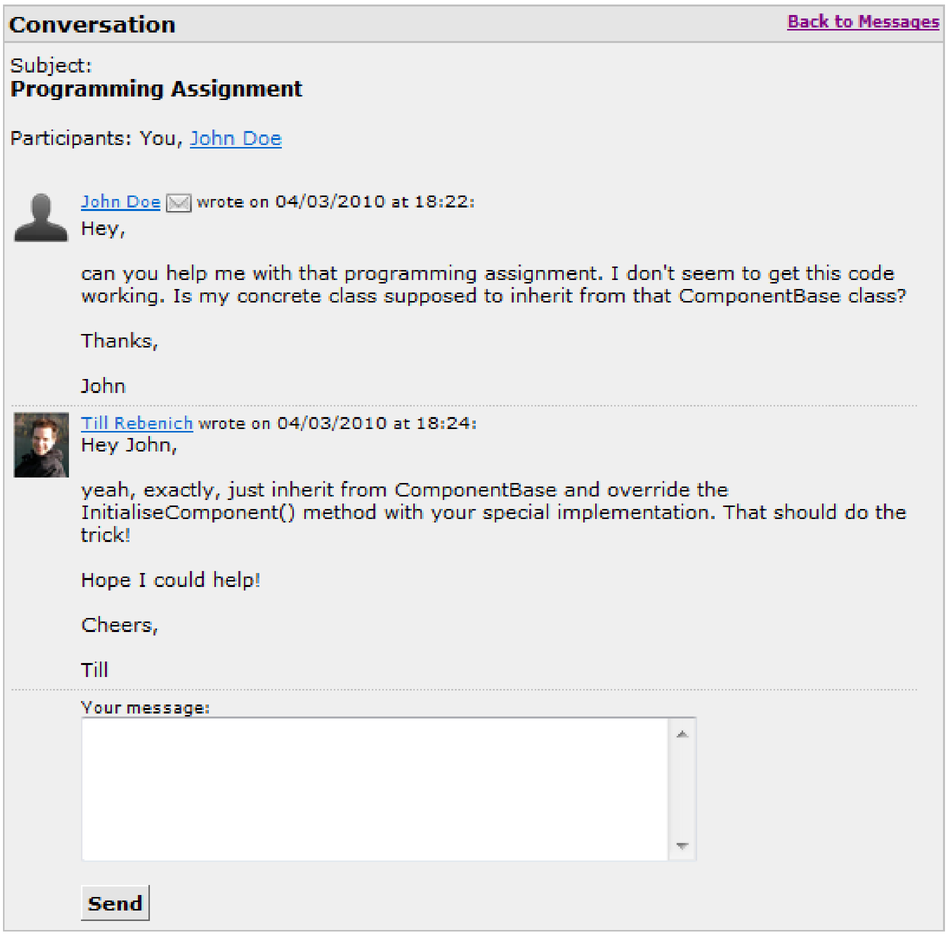


Figure 4.3.12: Conversation-based internal messaging system

User collaboration is enabled in collaborative tasks defined in the context of a group. Each collaborative task can be assigned to one or more group members, defining a *collaboration space* or *project*. This is shown in Figure 4.3.13 and allows fine-grained control over each member's responsibility with respect to a task. The communication between collaborating users takes place implicitly, each collaborating user can keep track of their colleagues' contribution by them submitting progress reports, or explicitly, using any of the communication types mentioned in the previous paragraph or by attaching notes to a task. Task notes are visible to all group members.

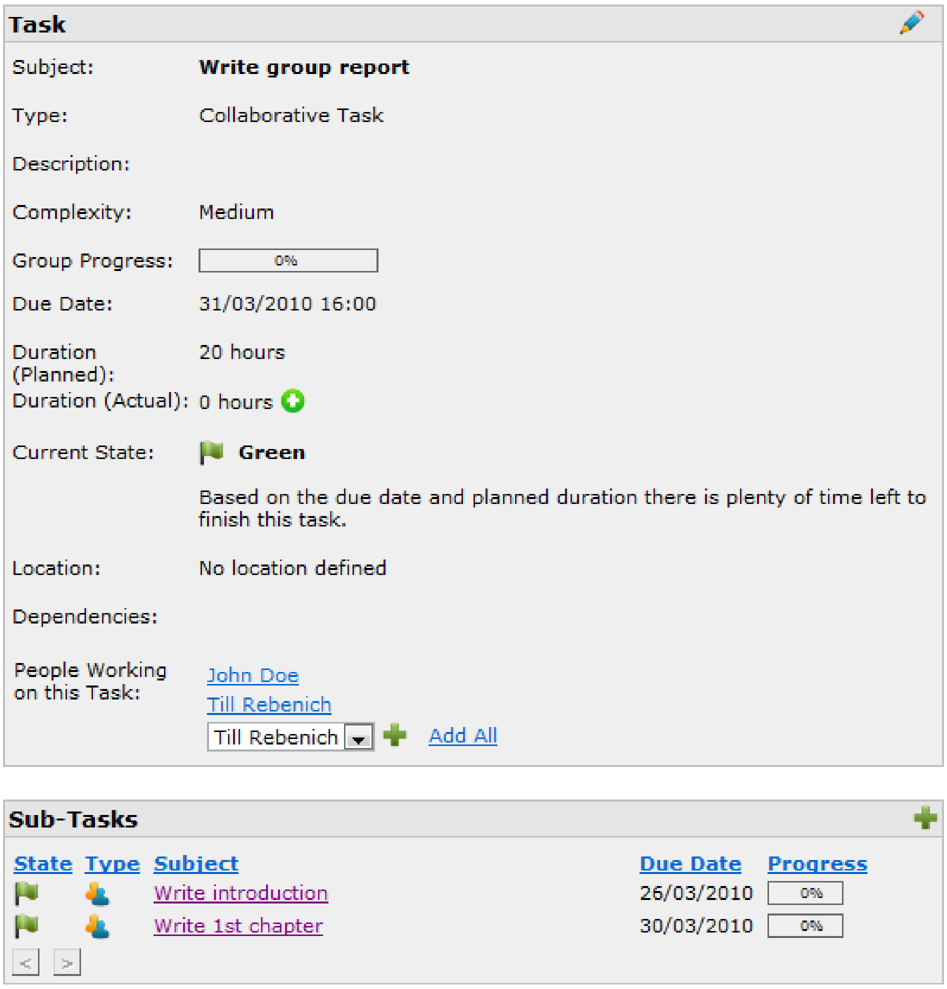


Figure 4.3.13: Collaborative tasks with two sub-tasks, further dividing work between the two collaborating users

Enhanced Presence Enhanced presence introduced by Eisenstadt and Dzbor [2002] is implemented as a virtual map displaying all users associated with the logged-in user, and all location-bound tasks and events as different icons. Moving the mouse over an icon results in additional information to be displayed for the underlying item. An associated user with regard to the current user is any member of any group the current user is also a member of. In Definition 4.6, the set of all groups g_i containing the current user u_c is given as $M_u = \{g_1, g_2, \ldots, g_n\}$. Furthermore, let $M_g(g)$ be the set of all members u_i of group g, then the set of associated users A_u with regard to the current user u_c is defined as

$$A_u = \bigcup_{i=1}^{n} M_g(g_i) \setminus \{u_c\}$$

with $n = |M_u|$. However, only users whose geographical location l_u is within a 2-kilometer radius of the current user's geographical location are displayed on the map (see Figure 4.3.10a).

Another enhanced presence aspect is the tasks a user is currently working on. These can be chosen from the grouped task list view described above and pinned to a special area which is called the *current work set*. This functionality is shown in Figure 4.3.14. Once

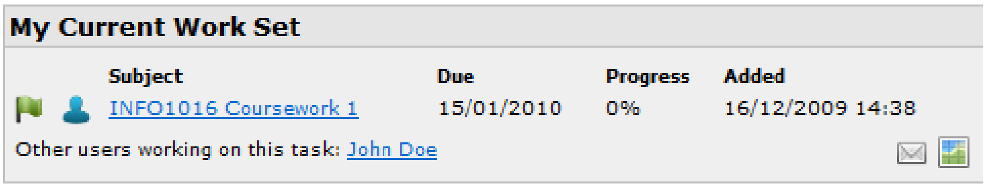


Figure 4.3.14: Current work set

a task has been pinned to the work set, the system shows all users currently working on the same task s or any of its sub-tasks s_s, taking only group tasks into account. Their position can then be displayed on the map or the current user can choose to contact them directly by clicking on the map or envelope icon, respectively.

User Motivation User motivation is achieved in two ways. Firstly, users can see the latest changes of groups and tasks they can access, and also who else has recently made progress on them. This information is displayed in the news feed (see Figure 4.3.10b). Also, the grouped task list view always shows the current user's progress and an indicator (either a red minus or green plus sign) of how that relates to the average progress of all group members. In this context, there are several scenarios aimed at motivating users to act:

1. The majority of other group members has already started working on a task, and this might encourage those who have not yet started to do so as well, yielding a feeling of competitiveness and peer pressure.

2. A user has added a note to a group task and its content might make other users become aware of possible difficulties.

3. In collaborative contexts, a user's contribution to a task can encourage other collaborating users to contribute as well. The availability of task progress information increases the participating users' sense of a learning community, which is claimed to have a motivating effect [Mochizuki et al., 2008].

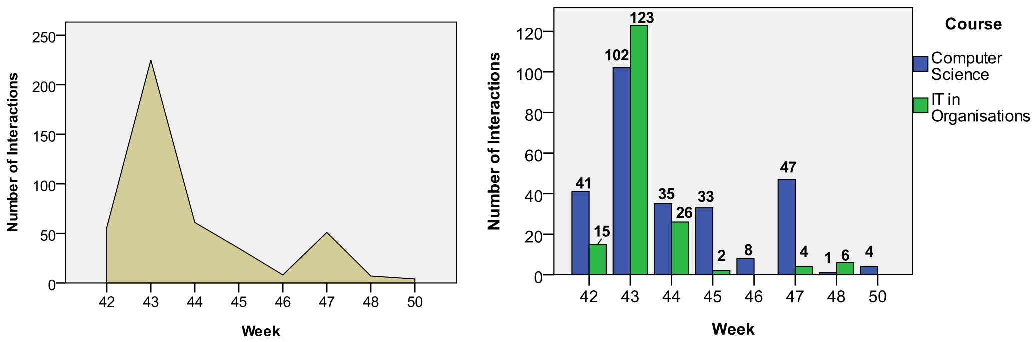
Users can also refer to the detailed task statistics which are displayed on the task details view (see Figure 4.3.11), also providing the actual effort made on the task by other users. In addition, this might encourage them to contact individual users in the list to seek advice or help.

4.4 Results

The first semester of the academic year 2009/2010 ended on 30 January 2010, and some results are available from usage data collected in the system during that time. For analysis purposes, the data was aggregated using two system interaction data sources:

1. User activity directly related to tasks, events, groups, and notes added to these entities. More specifically, this includes the creation and modification of tasks and events, progress made on tasks, group membership activities, and notes attached to tasks or groups.
2. User browsing behaviour, that is, access of event, task, group, and user pages, as well as geographical position detection, chat feature usage, and calendar export data.

Any instance of such an activity (1) or browsing behaviour (2) is called an *interaction*. In the first place, system usage, that is, the total number of interactions over time, was analysed. The results are presented in two levels of granularity. Figures 4.4.1a and 4.4.1b show the number of interactions per week, and Figure 4.4.2a the number of interactions per month. The total number of interactions over the whole trial period (semester) is depicted in Figure 4.4.2b. In all cases, one can compare the system usage of students in both courses of study, namely computer science (CS) and information technology in organisations (ITO).

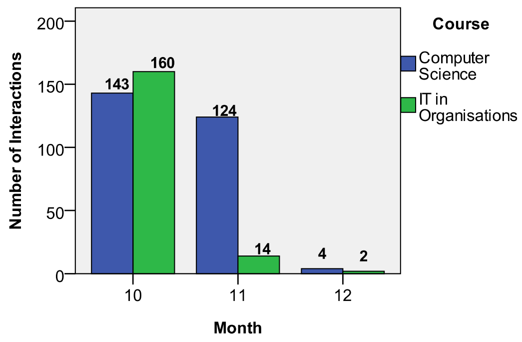


(a) Overall usage per week

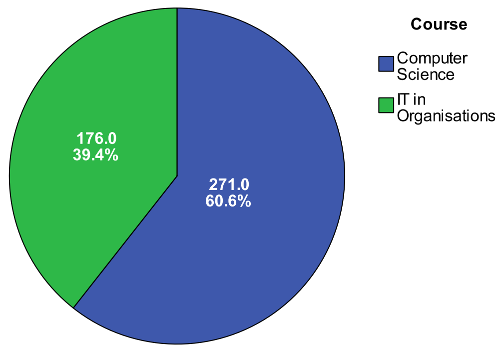
(b) Usage per week and course of study

Figure 4.4.1: System usage over time

The overall usage pie chart (Figure 4.4.2b) reveals that participants from the CS course used the system more frequently than those from ITO. This is not surprising given the trial group distribution shown in Table 4.2. In total there were 32 participants in the trial group in semester 1, 24 of which were CS students and 8 ITO students, making up 75% and 25% of all semester 1 trial group participants, respectively. However, the analysis of system usage over time (Figures 4.4.1 and 4.4.2) shows that ITO students used the system more frequently during the third teaching week (calendar week 43) of



(a) Usage per course of study and month



(b) Overall usage per course of study

Figure 4.4.2: Usage per course of study

the semester, that is, most interactions occurred in the second week after the system was introduced. As the usage pattern in Figure 4.4.1a suggests, usage dropped quickly after week 43, reaching a low in week 46, and its absolute minimum in week 50. There was a slight increase in calendar week 47. Also, participants in the trial group made absolutely no use of the system in January 2010. This is also reflected in the total number of system users plot shown in Figure 4.4.3.

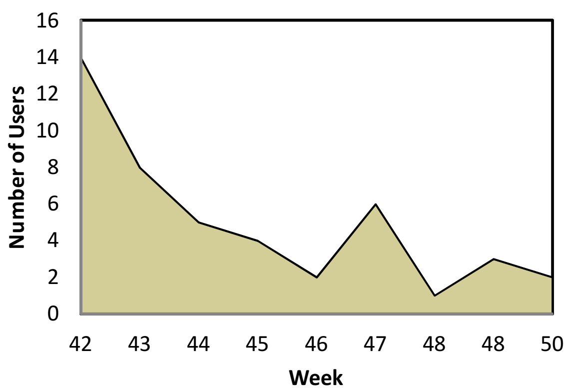
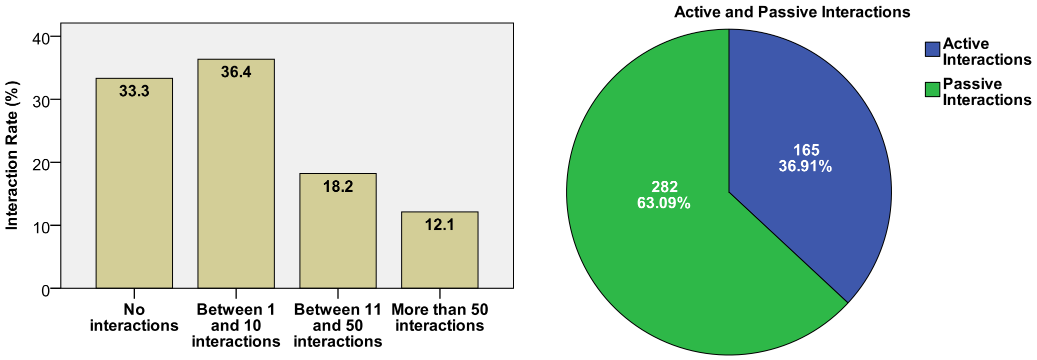


Figure 4.4.3: Weekly numbers of system users

Looking at the distribution of interactions in relation to participants, Figure 4.4.4a shows that the majority of students (69.7%) in the trial group used the system very sporadically, making either no or only very few (up to 10) interactions, while only 12.1% made more frequent use of the system. Those with no interactions did not even log onto the system once during the trial period.

One can also analyse interactions in terms of their type. As Figure 4.4.5 reveals, browsing the system's group structure makes up the majority of interactions, followed by browsing tasks, user logins, and viewing other user's profile pages. In total, only 28 progress reports were submitted on group tasks and 5 on private tasks. Clearly, the majority of tasks in the system were group tasks, and a mere 2 users actually managed a private task on the system. It also appears that automatic position detection occurred in only 7



(a) System-user interaction rate (b) Active and passive interactions

Figure 4.4.4: Interaction rate and active/passive interactions

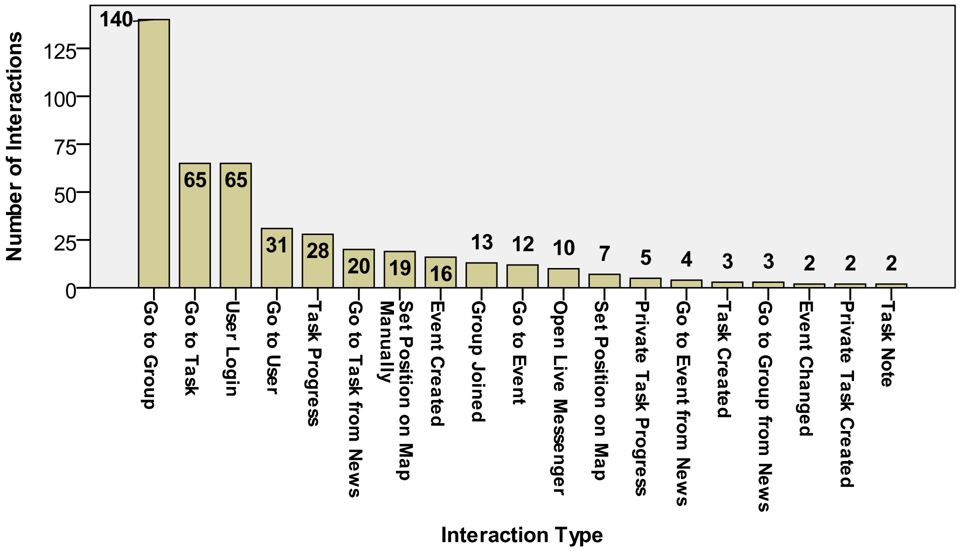


Figure 4.4.5: Usage per interaction type

instances, while the position was set manually in 19 instances. Furthermore, the chat feature (Windows Live Messenger) was accessed only 10 times, but no actual user chat was ever initiated. Similarly, there have been no records for the following interaction types over the whole trial period: iCalendar file export, creating and modifying private events, and the exchange of messages using the built-in messaging feature.

Furthermore, interactions can be characterised as *active* and *passive*. An interaction is active if it is triggered by an activity which is aimed at other users becoming engaged in a user-to-user interaction or if it results in a visible modification of system entities (profile, task, event, location, and so forth). Generally, every activity leading to a user contribution or input in terms of data provided by them is an active interaction. In contrast, every activity which is solely aimed at retrieving and consuming information (output) is a passive interaction. The distribution of active and passive interactions over the trial period is shown in Figure 4.4.4b.

4.5 Discussion

There are several factors which were crucial for the success of the experiment described here. First, the overall helpfulness of features concerned with enhanced presence (see section 2.4 on page 56) and workspace awareness (see section 2.4 on page 56) is highly dependent on the degree of participant activity in the online system. Activity in this context refers to the number of active participants and the frequency of user-system interactions. In each of the two courses from which participants were recruited, experiment participation rate was approximately 52%. However, participants in each course were then split into trial and control groups. This resulted in a further reduction of the number of active system users, thereby also reducing the chance of high user-system interaction numbers. This is also reflected in the results of the trial, especially in the overall usage graph shown in Figure 4.4.1a. The usage frequency peak in week 43 can be explained by an email which was sent out to notify users in the trial group, and the second (much lower) peak was in week 47 when a further reminder email was sent. In weeks 45 and 46, and then from week 48 until the end, a very sharp downward trend is noticeable. Furthermore, there was no activity whatsoever in January. These findings can be interpreted in the following way:

1. The system failed to motivate students and they obviously saw little relevance to their studies. This might also explain why the response rate to the reminder email in terms of user interactions was much lower in week 47. However, it should be noted that all participants were first-year students, and that the marks they gain in the first year do not count towards their final degree grade. Furthermore, the experiment was designed to leave students complete freedom over their system usage. There was no requirement for a certain degree of effort, in fact, students could choose not to spend any time at all on the experiment. In light of the results presented above, this experiment design was clearly ineffective and flawed.

2. The system was very detached from other student support systems provided by the school. For example, each module provides a syllabus and course notes website, and some modules also use student wikis. These systems have recently been integrated into a central course website from which students can then access each of the subsystems with ease. In contrast, the experiment prototype was not integrated into this central site and it required students to log on separately. It is likely that students simply forgot about its existence or spared the effort required to access it. Moreover, data about each module, such as assignment deadlines and examination dates, were not imported from other systems, and students had to verify that all data is correct and make amendments if necessary. This idea of a self-organising system required each participant to take responsibility for their personal study planning, thereby also supporting other less organised students, which they could not be encouraged to do.

3. The current prototype version does not include email notifications features. Students were expected to use the software on a regular basis. Although they could export all dates to an iCalendar-capable calendaring software, no student used this feature. A more proactive system behaviour, that is, regular email notifications about tasks becoming due and examination dates approaching, might have led to more students using the system more frequently. For example, research conducted by Girgensohn and Lee [2002] suggests that the number of online sessions goes up by 60% on days email notifications are sent, and page requests are up by 80%. The reason, they suggest, is that notifications make users aware of the existence of the system. Farzan et al. [2008] report similar effects.

4. No inducement was used in this experiment.

5. The fact that no activity was recorded for January 2010 could be explained by students being deeply engaged in coursework and exam revision which typically take place at the end of January. Although the system was aimed at supporting students in their revision and coursework planning, it seems that participants preferred using other tools.

6. Communication features such as system-internal messaging and instant messaging (chat) were not used by students. Since the chat functionality is based on Windows Live Messenger technology, students were required to sign up for a Windows Live ID, and they were obviously reluctant to do so. Similarly, it is not clear from the results whether users preferred conventional email for these purposes because this communication took place outside the system boundaries.

Second, students were randomly assigned to either trial or control group, taking gender distributions into account. This was to ensure that the experiment remained unbiased. However, this procedure neglects existing relationships between students in the target population, that is, each of the two courses. In this context, *relationship* refers to a relatively firm bond between individual students, for example, a group of friends or companions, a group of students usually collaborating on many assignments, or a reading or study group. Although such relationships are unlikely to be numerous in the first study year as they usually build up over the course of the programme, a random group allocation incurs the risk of breaking them. This may result in the system becoming unattractive to all members of such a group because most of the features supporting student collaboration would be unusable or irrelevant. It does not become clear from the results whether this was the reason for so few collaboration features being used. However, most of the participants who used the system remained passive, that is, they were information consumers while making insignificant or no contributions. Consequently, just under two thirds of all system interactions (63.1%) were passive, and only 36.9% were active (see Figure 4.4.4b).

Third, participants might have been overstrained and uncertain about how to use certain features. Although an introductory workshop was provided at the beginning of the experiment, only very few participants attended.

In conclusion, participation in the first semester was very sporadic. In light of the high proportion of participants showing no or between one and ten interactions (see Figure 4.4.4a), it is arguable whether the system prototype has had a significant effect on students' time management behaviour, their academic performance, stress, or learning experience. Consequently, a correlation analysis of their performance data (marks and coursework hand-in statistics) is unlikely to generate meaningful results and insights.

Chapter 5

Computer-Supported MSc Project Monitoring

The results of the experiment described in the previous chapter suggest that its primary research objectives cannot be achieved at this time. Consequently, new opportunities for collecting meaningful and sufficient data needed to be found. As this research is conducted in a university environment, it is heavily dependent on the curriculum. All academic staff involved need to support the experiment and actively encourage students to participate, resulting in the study being more deeply embedded in the students' curriculum and hence more relevant to them. In order to address these issues, a second research study was conducted in the school, using a web-based information system for monitoring Master of Science (MSc) summer projects. The results of the first experiment helped in designing this new study, whereby some of its aspects and objectives were retained.

The main aspects incorporated into this new study are: (1) time and project management in individual student projects, (2) progress and event attendance tracking, (3) enhancing student motivation and progress awareness using various visualisations of progress data, and (4) combining these techniques with an educational strategy (a monitoring scheme described in section 5.2). These aspects directly correspond to the four technology-supported learning aspects (TSLAs) outlined in section 2.7 on page 68. Details about concrete system features supporting these aspects are provided later in this chapter.

The following sections describe the motivation for and primary objectives of this study. The differences between this and the previous study are shown in Table 5.1.

5.1 Motivation

As in other UK universities, the Master's degree typically takes one calendar year and is concluded by a three-month summer project during which students are expected to do independent research and practical work on a well-defined project. The summer project

Table 5.1: Comparison of the two research studies

Characteristic	Study 1	Study 2
Target group	Undergraduate first-year Bachelor students	Postgraduate Master students
Degree type	Taught	Taught
Participants	65 (53 male, 12 female)	378 (290 students, 69 supervisors, 19 monitors)
Setting	Taught module, assessed by coursework and examination	Project-based learning, assessment based on dissertation
Research design	Experimental	Quasi-experimental, observational
Prototype	Online study planning system	Monitoring system
Performance indicators	Module marks, hand-in statistics	Taught mark, dissertation mark
Other data	Survey data	Survey data, informal interview data, historical data
Time frame	6 months (2 semesters)	17 weeks (summer)

follows the taught part of the MSc in which students take a set of compulsory and optional marked modules. All module marks are later combined to form a so-called "taught mark". Then, during their summer project, students are supervised by at least one academic in the school. At the end of the project, students submit a 15,000-word dissertation about the topic they have been working on, which is then marked independently by two or three examiners. The first examiner is usually their project supervisor, the second examiner is another member of academic staff in the school, and the third examiner only becomes involved if there is a considerable difference between the marks issued by first and second examiner, in other words, if both cannot agree on a project mark and if the difference is too high. More specifically, the school marking policy requires that both examiners compromise or average their marks if they differ by 5% or less. If no agreement is reached and the difference is 5% or more, or if a failing project mark is issued, a third examiner must be appointed.

The concept of MSc projects is centred around the idea of project-based learning, however, not in the context of the classroom but for each individual student. In project-based learning, students face the challenge of autonomously working on a given task, investigating a problem, making decisions, planning their work, and coming up with suitable solutions [Thomas, 2000]. Others such as Blumenfeld et al. [1991] elaborate on the importance of project-based learning as "learning by doing" and appropriate tool support for sustaining student motivation and teacher engagement in the course of the project. So far, a lot of research has been done on combining features of collaborative learning and project-based learning, that is, project-based learning in the classroom or in teams. In particular, Mochizuki et al. [2008] have focussed on visualising the division of labour between students working in the same project team by raising their context and task awareness. However, managing MSc projects is somewhat different from typical project-based learning scenarios. They are designed to be individual, in other words, students do not work together on projects, or if they do, they focus on different aspects or components to ensure that they each make an individual contribution. Consequently, there is a very small or no collaboration aspect in these projects.

Nevertheless, the summer project is one of the most challenging parts of every MSc degree. Firstly, students only have a limited time available to complete it, and secondly they are required to work independently during this three-month period. Despite of regular meetings with their supervisor, there are only a few formal milestones at which students have to submit deliverables giving account of their progress. In light of this, good time management and project planning skills are crucial success factors. Since student autonomy is a key aspect of such projects, learner self-regulation is particularly important.

These general risks coincide with some exceptional circumstances arising in the 2009/10 academic year in the school. The annual student intake had risen by 73.1%, from 171 in 2008/9 to 296 in 2009/10, posing additional challenges to both students and staff. It was anticipated that project monitoring and supervision would become more difficult given that academics have to supervise more MSc students. This could lead to more difficulties remaining undetected and a higher workload for those academics involved in MSc supervision.

In order to mitigate these risks and to provide students with regular and prompt feedback on their project progress, an MSc monitoring scheme was introduced whereby each MSc student was allocated to a monitoring group. Every group was led by a project monitor, usually a postgraduate research student, and met once every week. Project monitors were not involved in the marking of the project, nor did monitoring meetings replace the student's meetings with their supervisor. Details of this scheme are explained in section 5.2 below.

The monitoring scheme was supported by a newly developed web-based monitoring system providing features for personal project planning, meeting organisation and attendance tracking, progress and motivation feedback, and performance rankings and dashboards. Both the scheme and the system are also based on a small trial carried out in the summer of 2009, involving two postgraduate research students acting as project monitors for a subset of all MSc students in the school, however, without software support. The results of this trial were positive in the sense that monitors were able to support students and also predict which students would encounter difficulties in their project, but monitors recommended the development of an information system supporting their work.

5.2 Monitoring Scheme

The monitoring scheme was introduced in order to support MSc students beyond the traditional MSc supervision model whereby each student was assigned an academic in the school who acts as their project supervisor and first examiner. The monitoring scheme did not replace this supervision model; it was meant to mitigate problems arising from the exceptional workload on supervisory staff in the academic year 2009/10. Furthermore, it was used as a pilot to test its effectiveness and to decide whether the scheme will be continued, especially in light of the fact that student numbers are expected to increase further in the following years.

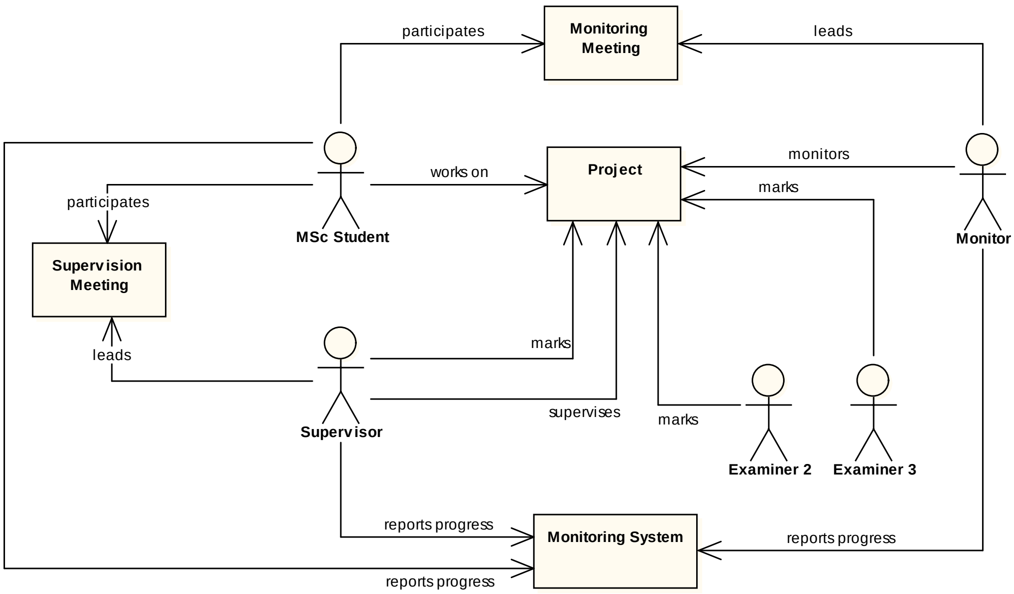


Figure 5.2.1: Monitoring scheme

Figure 5.2.1 shows a schematic overview of the monitoring scheme design. There are five actors, namely the MSc student, their project supervisor, the monitor, and two examiners. As mentioned before, the project supervisor also acts as an examiner, constituting a total of up to 3 examiners. Each MSc student works independently on their project, which is supervised by their supervisor. In many cases, students have the freedom to choose the topic themselves and then discuss its suitability and the scope of the project with their supervisor, in other cases their supervisor provides a suitable topic. Project supervision takes place as a sequence of meetings between student and their supervisor. The frequency of these meetings is at the discretion of both parties, but the school recommends that they should be held every week. In addition to these supervision meetings, each MSc student is assigned a monitor whose responsibilities are to (i) provide technical support, for example, where laboratory work, special computer systems, or particular technologies are required as part of the project, (ii) give general feedback or advice on the project or project-related matters such as project and time management,

(iii) encourage student peer support, and (iv) record progress and motivation-related data on the newly developed monitoring system. For this purpose, each monitor meets their group of up to 10 students once a week. The structure of these meetings is rather informal with each participant reporting their progress to the group, raising existing or imminent problems, and getting feedback from the rest of the group and the monitor. This is based on the idea of Scrum meetings. Scrum was originally developed by Schwaber and Beedle [2002] for managing software projects, but can also be applied to project management in general [Schwaber, 2004]. In a scrum meeting, every member of the Scrum team answers three questions:

1. What have you done since the last meeting?
2. What are you planning to do until the next meeting?
3. Are there any problems preventing you from achieving your target?

Furthermore, a Scrum master is appointed for each project whose role is to deal with any difficulties arising during the project, in other words, any issues mentioned by team members in response to question number 3.

In monitoring meetings, an adapted version of this approach is used, whereby the time between each meeting it typically one week, and the monitor asks each group member about their progress so far, their plans for the next week, and any issues they are experiencing. If difficulties are raised by a member, the following two-step process is applied: first, the monitor encourages peer support, that is, other members get the opportunity to comment on the issue and suggest possible solutions; then, in the second step, it becomes the monitor's responsibility to remove the impediment.

The attendance of monitoring and supervision meetings is strongly recommended to all MSc students in the school, however, students' attendance of monitoring meetings as well as monitoring system use do not influence their marks. Supervisors and students are strongly encouraged to use the monitoring system for recording progress, motivational state, and for managing their weekly tasks and meetings, but they are not required to do so.

5.3 Objectives and Hypotheses

The key emphasis of this research is on computer support for self-regulated learning, following the model of Zimmerman [2011] depicted in Figure 2.1.1 on page 25. In particular, four central technology-supported learning aspects (TSLAs) have been identified: (i) motivation, (ii) time management, (iii) progress awareness, and (iv) monitoring. As outlined earlier, these aspects are key catalysers of self-regulated learning in all three phases:

1. Self-motivation beliefs are influenced by students' self-efficacy, their outcome expectancies, interest in the learning task, and their goal orientation. These, in turn, are affected by feedback generated from monitoring processes. Prior research suggests that motivated students are better in planning their work, show higher perseverance, and are more likely to embark on difficult learning tasks.

2. Time management is important for (i) task analysis, including goal setting and strategic planning, and (ii) during the performance phase, that is, when student work on their learning tasks. Good time management positively affects monitoring since clear progress metrics have been defined for each of the tasks, and prior research suggests that students who use time management strategies also attain higher performance (grade point average).

3. Progress awareness contributes to students' relative ability goal orientation. In other words, progress and performance data of other students working in the same or similar project contexts indirectly affects students' self-motivation beliefs.

4. Monitoring is the process of generating meaningful feedback for students, which is used for self-reflection purposes. Students evaluate their own progress based on such feedback and also reflect on the cause of problems, resulting in a particular adaptive or defensive reaction. Monitoring can also be regarded as a collaborative activity, for example in peer support scenarios. The monitoring scheme described in the previous section was designed to support this activity.

The TSLAs are also associated with four of Chickering and Gamson's [1987] seven principles for good practice in undergraduate education, which are described in detail in section 2.6 on page 66. In particular, time management corresponds to principle 5 (putting time on task first), motivation to principle 1 (encouraging student-faculty support), progress awareness as well as monitoring to both principle 4 (provision of prompt feedback) and 6 (communicating high expectations). The remaining principles (student cooperation, active learning techniques, and respect for diverse talents) were not directly supported by technology but implicitly by the monitoring scheme, and therefore no data relevant to these principles was collected. Chickering and Ehrmann [1996] also made recommendations regarding suitable technologies for implementing the seven principles in e-learning applications (see Table 2.5 on page 68). Since 1996, available tools and technologies are likely to have evolved and changed considerably. One objective of this work is the refinement and extension of this list, based on statistical analysis of data collected in this research study.

In light of this, a web-based monitoring system was designed and used over a period of 17 weeks for monitoring MSc projects in the school. It provided features for (i) encouraging professional project planning, (ii) enhancing student motivation using progress awareness and social presence, (iii) facilitating user-to-user and in-group interactions, and (iv) enabling difficulty detection for academic staff and monitors. In the context of this research study, the following main hypotheses are made:

Hypothesis 5.1. The use of software features supporting the TSLAs motivation, time management, progress awareness, and monitoring positively affect students' self-regulated learning in individual project-based contexts. In particular,

1. Motivation features positively affect student motivation and academic performance by enhancing students' self-motivation beliefs, and transitively their achievement.
2. Time management features positively affect student progress and academic performance by means of enhancing students' self-control mechanisms and self-observation behaviour.
3. Progress awareness features positively affect student motivation by influencing students' relative ability goal orientation, and transitively their academic performance.
4. Monitoring features positively affect student progress, motivation, and academic performance, influencing their self-judgement and reaction to feedback, which is the outcome of the monitoring process.

Hypothesis 5.2. The use of TSLA features leads to measurable changes in student perception and behaviour which are explained by reference to the four selected principles introduced by Chickering and Gamson [1987]. These measurable changes are (i) perceived helpfulness for project management, (ii) perceived motivational effect, (iii) motivation ratings, (iv) progress ratings, (v) academic performance, (vi) usage statistics, and (vii) correlations between aforementioned measures. They demonstrate the importance of these features for project-based self-regulated learning and lead to a refined list of technologies supporting these principles based on Chickering and Ehrmann [1996]. In particular,

1. Changes associated with electronic progress, event attendance feedback, and group interaction features support the "enhance student-faculty contact" principle
2. Changes associated with time management features support the "putting time on task first" principle.
3. Changes associated with progress awareness features support the "prompt feedback" and "communication of high expectations" principles.
4. Changes associated with monitoring features support the "prompt feedback" and "communication of high expectations" principles.

Hypothesis 5.3. Monitor feedback and activity positively affect student motivation, performance, and system use in the context of this research study, showing that the educational strategy in combination with software support was effective.

5.4 Study Design

To establish whether the above hypotheses hold, a quasi-experimental study design was chosen [Field and Hole, 2006], since there was only limited control over the independent variable (system use). In particular, a random division of participants into trial and control groups could not be achieved because it was a school requirement that all MSc students should be able to use the system. Moreover, there was no control over whether or not and how frequently participants use the system. The study design is depicted in Figure 5.4.1.

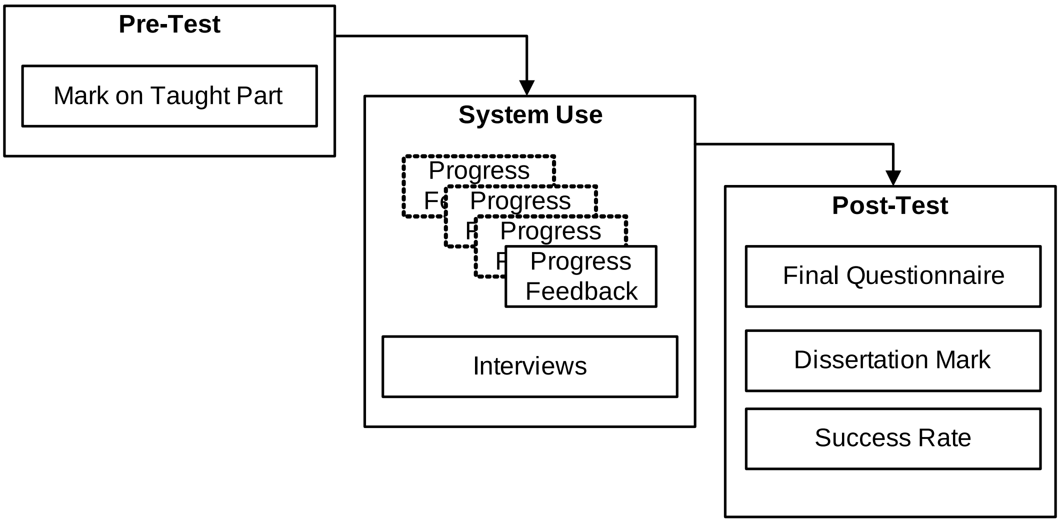


Figure 5.4.1: Study Design

Furthermore, a one group pre-test/post-test design was applied. Academic performance was measured at the beginning (the mark students gained on the taught part of their MSc) and at the end of the experiment (the project/dissertation mark). Also, an interrupted time-series approach was taken whereby project supervisors, monitors, and students themselves assessed overall student progress and motivation in weekly intervals over a 17-week period using the web-based monitoring system provided.

Both quantitative and qualitative methods were used in the study. Quantitative data consists of system logs and subjective participant feedback given through the system and questionnaires, while qualitative data was gathered using semi-structured interviews and questionnaires.

5.4.1 Setup

Before the start of the study, the development of the online monitoring system had to be completed, the system be tested and deployed, ethical issues be dealt with, and students be allocated to monitoring groups under the scheme described in section 5.2. The system design and its development are outlined in section 5.5.

In the study, personal student data falling under the Data Protection Act was recorded. However, the monitoring system was officially approved by the school and therefore regarded as a teaching support system. As such, all data recorded can be used for evaluation and quality assurance purposes under the regulations of the university calendar each student acknowledges at the time of enrolment. Furthermore, the ethics committee approval filed under reference "N/09/09/02" (see Appendix B for details) still applies on the grounds that the monitoring system used in this study comes with a sub-set of the features used in the previous study (see 4.2) and since it explicitly contained the option to repeat the experiment with other population samples. Furthermore, the chair of the ethics committee was consulted and suggested that no further approval was necessary for this particular case.

All 290 students who were studying on an MSc degree in the school and had passed the taught part of their programme, 19 monitors – mainly postgraduate research students – who were recruited from research groups, and 69 supervisors participated in the study, making up a total of 378 participants and hence potential system users. The proportion of students in each of the 11 MSc programmes is depicted in Figure 5.4.2.

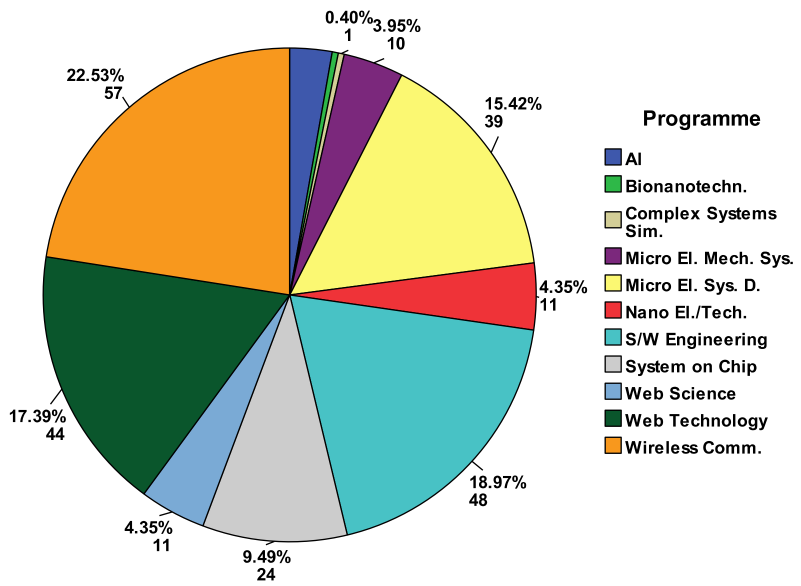


Figure 5.4.2: Student Participants

Students were allocated to exactly one of 38 monitoring groups, together with other peers working in the same or very similar topic area. These groups were led by 19 monitors. The allocation within subject areas was mostly random, however, in some cases students' taught mark was utilised in order to group together students studying at the same level and to make groups more homogeneous. This allocation was done by a member of academic staff and could not be influenced, but needs to be considered later in the evaluation of the study. The number of students in each monitoring group was generally between 3 and 13, with the average per group being 6 and the median 5.5. Only four groups contained more than 10 students, mainly because it was infeasible to split them up into smaller sub-groups due to topic-related, supervision-related or other reasons. Furthermore, 65 students were not assigned to any monitoring group for the same reasons, for example, there were 39 referring students who failed some of the examinations in the taught part of their programme and started their summer project later, typically in October. A detailed breakdown of the number of participants is shown in Table 5.2. In the web-based monitoring system, a virtual group page was provided for every monitoring group. Details about features provided on these pages are explained later in this chapter.

Table 5.2: Study participant numbers

	N	% of Total	% of Students
Total participants	378	100	–
Students	290	76.7	100
Monitors	19	5	–
Supervisors	69	18.3	–
Students in a monitoring group	225	59.5	77.6
Referring students	39	10.3	13.4

5.4.2 Pre-Test

Before students can begin their summer project, they have to pass the taught part of their programme taking place in the first 9 months of the programme. This part consists of a number of taught units assessed by examination or coursework or both. If a student fails any of these units, they have to take a referral exam which is usually scheduled for September/October each year. Provided that a referring student passes their referral exam, they can proceed towards the MSc project. Invariably, this means that referral students will commence their project when all other students not doing referrals have finished theirs. The pre-test is thus the taught part of the MSc, and an individual student's performance is the total mark gained for this part. In the remainder of this report, this mark will be referred to as the *taught mark*. Experience and statistical analysis have shown that students' average dissertation mark is slightly higher than their taught mark. In ECS, for example, the means of both marks were significantly different in 2009 ($t(142) = -5.849$, $p < 0.01$, $r = 0.563$, $\Delta\mu = -3.678$) and 2010 ($t(273) = -6.881$, $p < 0.01$, $r = 0.458$, $\Delta\mu = -3.235$), but not in 2008 ($\Delta\mu = -1.2197$). However, both marks also highly and positively correlate with each other with $r = 0.551$ and $p < 0.01$ for 2008, $r = 0.662$ and $p < 0.01$ for 2009, and $r = 0.660$ and $p < 0.01$ for 2010, respectively. This indicates that in recent years, mean differences between both marks were fairly similar ($-1.2197 \geq \Delta\mu \geq -3.678$) and between-mark correlations showed similar effect sizes ($0.551 \leq r \leq 0.662$). Furthermore, the majority of taught units in ECS contain coursework components, mainly consisting of mini-projects or technical assignments which have a similar character as the summer project but usually take much less time.

5.4.3 Treatment

As mentioned earlier, the study is not strictly experimental since there were some limitations regarding the control over experimental groups. Therefore, the term "treatment" might be misleading. Here, it is used to refer to the active phase of the study, where participants could use the monitoring system. During the treatment phase of the study, students, monitors, and supervisors were asked to use the web-based monitoring system for planning project work, organising meetings, recording progress data, progress tracking, and in-group communication – their participation in the monitoring scheme was implied since it was compulsory. For the purpose of progress tracking, students, monitors, and supervisors were asked to rate the overall project progress and student motivation every week on a scale ranging from 0 (not seen) to 5 (outstanding), where "not seen" indicates that staff did not meet with the student in the corresponding week. In this context, a week starts on Monday and ends on Sunday, and users had all week to submit these reports. Furthermore, users were prompted to comment on written work seen and counting towards the final dissertation, that is, the word count of the body of the report, the page count of the report appendix, and the quality of both, again measured on a scale from 0 (not seen) to 5 (outstanding).

As part of the qualitative research, semi-structured informal interviews were held in three different computer science monitoring groups at the end of one of their weekly meetings. The aim of these interviews was to receive general feedback about the monitoring scheme, the online system, and to gain some general understanding of students' needs, their project management, any project-related problems, and thoughts on project monitoring and how it could be improved. The interviewing process involved (i) talking to the monitor before the start of the meeting, (ii) witnessing the actual meeting, and finally (iii) asking students for

- General feedback concerning the monitoring scheme and meetings,
- Feedback on the monitoring system features and their perceived usefulness,
- Suggestions for improving the system and additional features desired,
- Questions they have with regard to system features and their usage.

Short written notes were taken during the interview which are summarised later in this chapter. The comments of monitors and students were also used in combination with the post-test questionnaire results.

5.4.4 Post-Test

At the end of the MSc summer project, each student has to submit a 15,000-word dissertation. As described in section 5.1, this report is then marked by two or three examiners who have to agree on a final project/dissertation mark. In this study, the dissertation mark is the dependent variable since it represents a snapshot of the student's academic performance at the end of the summer project. It is established solely on the dissertation and the outcome of the project and hence completely independent of the student's prior performance, for example, in the taught part of their MSc. Furthermore, it is also independent of the intensity of students' system use.

In addition to the dissertation mark, subjective feedback from students and monitors was collected using a small online survey integrated into the monitoring system. The survey was aimed at evaluating

- The perceived motivational effect of certain system features,
- The perceived helpfulness of system features for MSc project management,
- General feedback on the efficiency of monitoring meetings, their frequency, and any action taken by supervisors and monitors in response to system activity,
- Other online or offline tools used for managing the project,
- Finally, general comments about the system and the monitoring scheme.

Participation in this closing survey was optional for all students and monitors. The complete outline of the questionnaire can be found in Appendix A.2.

5.5 System Design

This section describes the design of the web-based monitoring system used in the study. The development process started on the 20th of March 2010 and all stages had to be completed by the 14th of June when MSc students started their summer projects. With only one person (the author of this thesis) working on the system, a strict object-oriented and agile approach was taken. It resembled that described in section 4.2 on page 90 and consisted of the following iterative stages:

1. Requirements engineering: in this stage, the requirements of academic staff regarding MSc project supervision and monitoring, and research-related requirements were gathered.
2. Modelling: requirements, components, and classes were modelled based on the results of the previous stage. The software Sparx Enterprise Architect[1] was used in this process step for producing diagrams and generating code in the next step.

[1] http://www.sparxsystems.com.au

3. Code generation: based on the modelled classes and following the model-driven architecture (MDA) paradigm, code was generated and code changes reverse-engineered so that the model always reflected the underlying code.

4. Testing: due to the short time frame available, no separate unit testing was applied. Instead, components were tested separately from the user interface, and further components were iteratively added one after another during this process.

5. Data import: real user data was imported into a live database with the exact same structure as the test database.

6. Deployment: the tested system and the live database were then deployed to a virtual server and enabled for general use by students, monitors, and supervisors.

5.5.1 Use Cases

As part of the requirements engineering process, a number of use cases were created and added to two categories and hence diagrams, namely "Meeting Organisation" and "Project Organisation", which are shown in Figures 5.5.1 and 5.5.2.

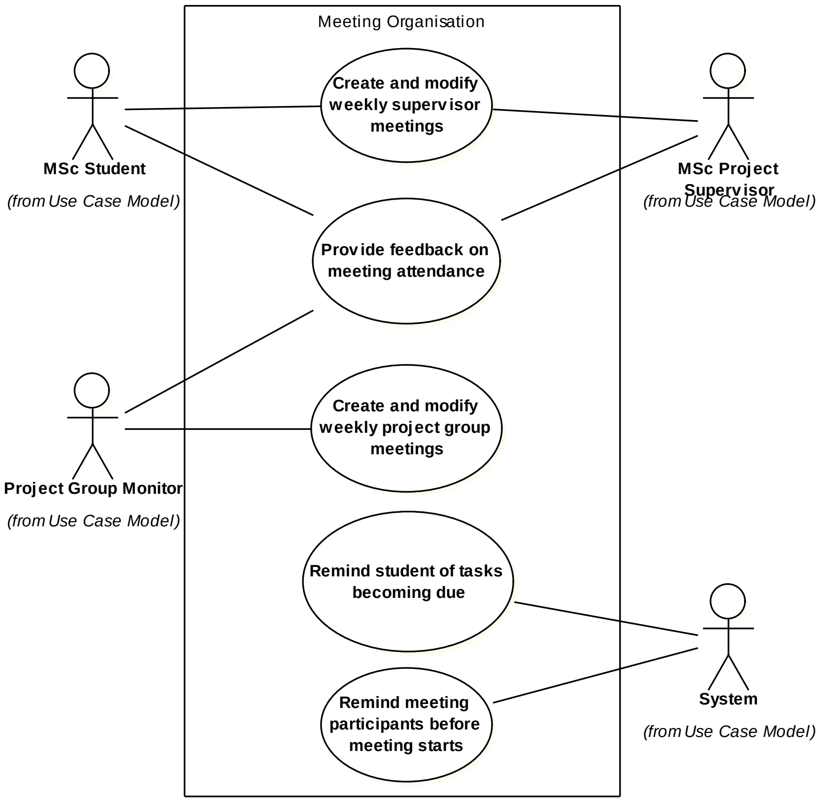


Figure 5.5.1: Meeting organisation use cases

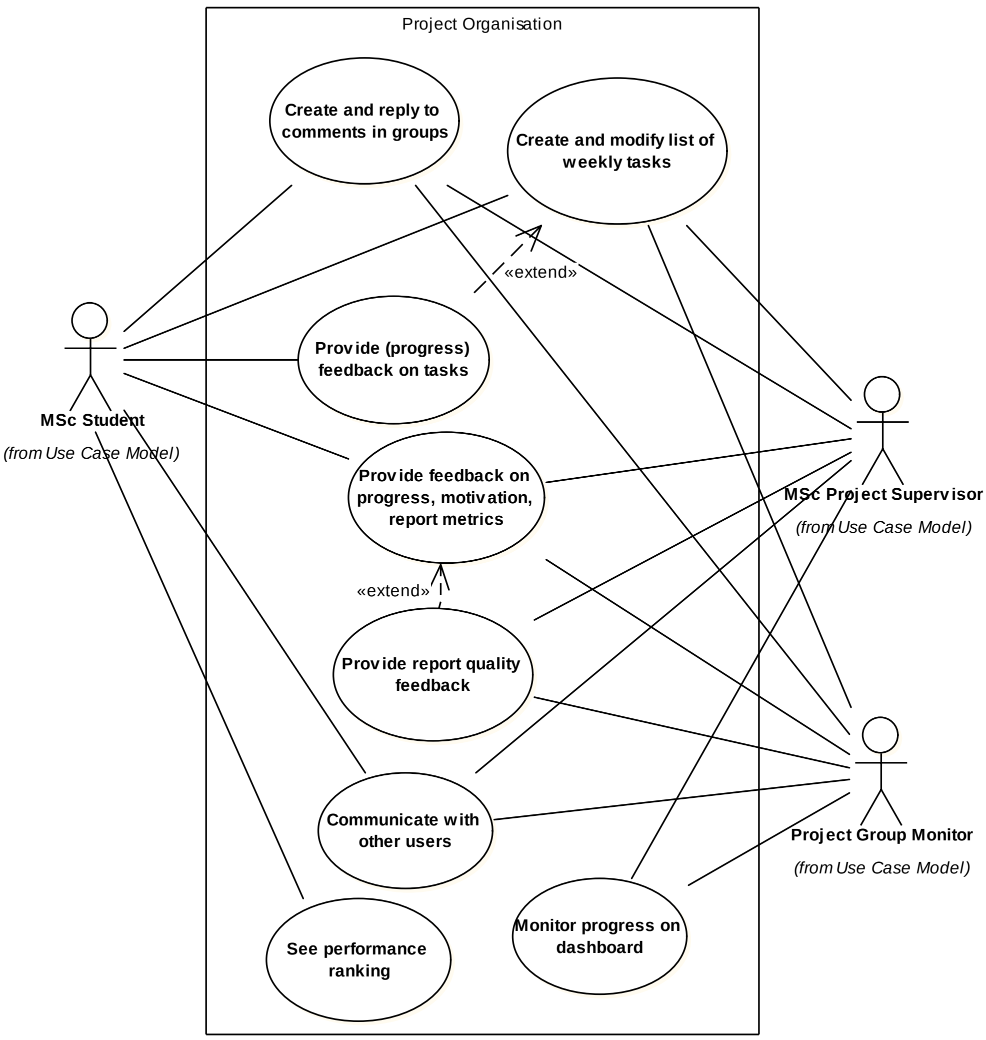


Figure 5.5.2: Project organisation use cases

5.5.1.1 Meeting Organisation

Meeting organisation is a central component of the system. While students are in charge of managing their weekly supervision meetings (with the option of their supervisor doing this as well), monitors are meant to manage weekly monitoring meetings in the group. For this purpose, the system provides a project page for each student and a group page for each monitoring group. Each user can only access the group they are assigned to. Typically, this is only their monitoring group page, but the system also supports another type of group, namely project groups, which are used by some academics to organise joint meetings with all students they are supervising. Figure 5.5.3 shows a screenshot of a project/group calendar.

One day before a project or group meeting is to happen, all participants are notified by email, and after the meeting they are prompted to provide feedback on meeting attendance. Feedback submitted by supervisors or monitors overrides that of students, for example, if a student indicated that they attended a meeting but their supervisor submitted a “did not attend” feedback, the latter feedback will be used in attendance and performance statistics dashboards, graphs, and the student ranking. Figure 5.5.4 shows a screenshot of the event attendance feedback submission screen for students.

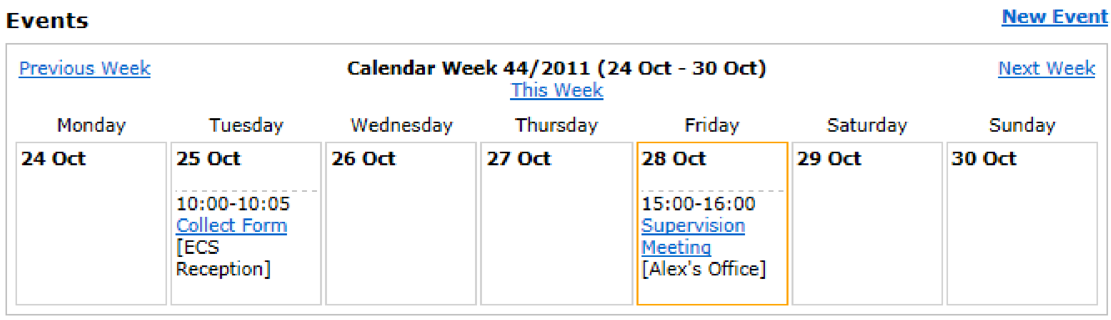


Figure 5.5.3: Project/group event calendar

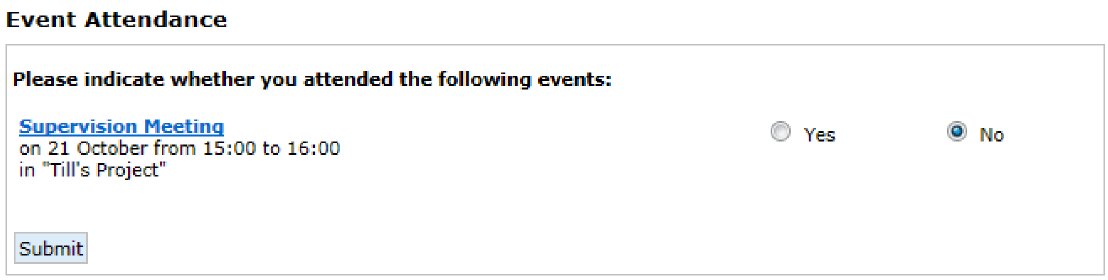


Figure 5.5.4: Students submitting feedback on their event attendance

5.5.1.2 Project Organisation

Another important system component is project organisation. It provides features enabling students to record their progress on weekly tasks, submit weekly feedback on their overall project progress, their motivation, and quantitative metrics of their report (see Figure 5.5.5). In addition to that, supervisors and monitors can submit qualitative report metrics and a textual comment containing further information. Monitors were required to provide such feedback as part of the monitoring scheme (see section 5.2), while this was optional for supervisors. Again, feedback provided by monitors override that of students, and supervisor feedback that of monitors. Also, email reminders were used to prompt users who have not yet provided these ratings to do this online. A detailed overview of the types of feedback submitted by the different types of system user is shown in Table 5.3.

Project organisation also includes the management of project tasks, which is supported by a simple and easy to use task list (see Figure 5.5.6). Each task has a title, description, start and due date, progress (percentage of completion), and a list of prerequisite tasks which need to be completed before work on the current task can begin. Furthermore, a set of predefined tasks representing project milestones is provided. Regular tasks can

Table 5.3: Progress metrics

Metric	Type	Variable	Origin
Overall project progress	Rating $[0, 5]$	p	Student, monitor, supervisor
Student motivation	Rating $[0, 5]$	m	
Word count of report body	Number	c_b	
Page count of report appendix	Number	c_a	
Quality of report body	Rating $[0, 5]$	q_b	Monitor, supervisor
Quality of report appendix	Rating $[0, 5]$	q_a	

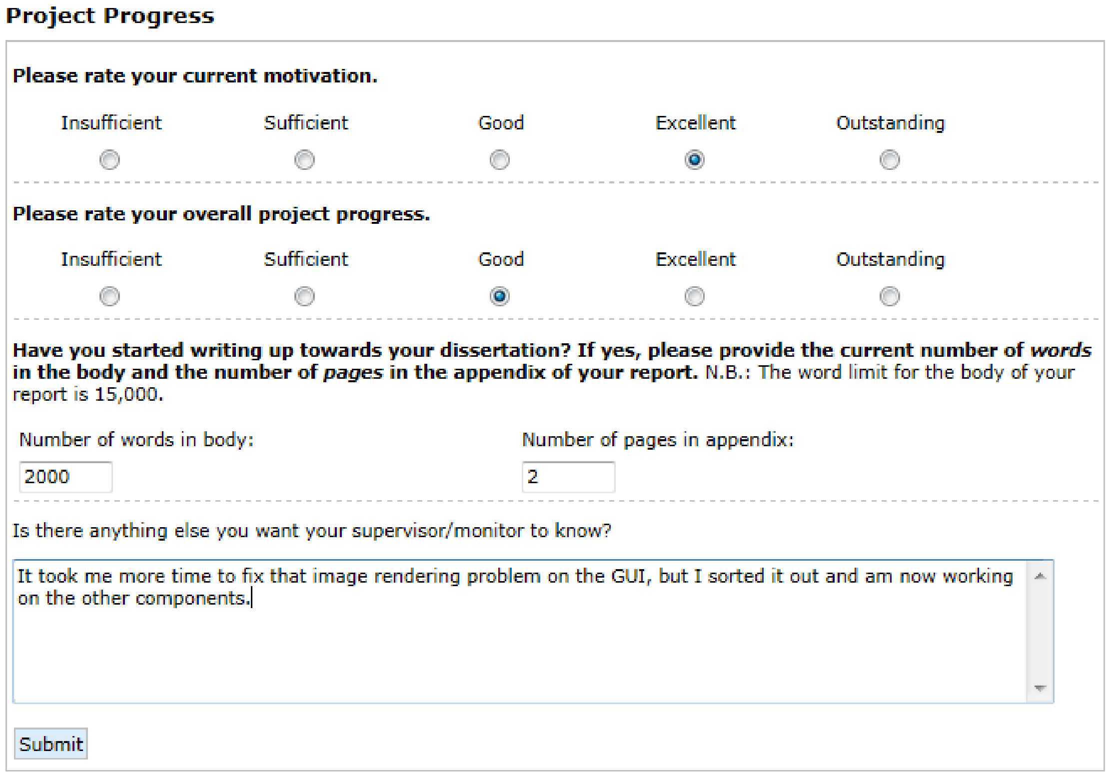
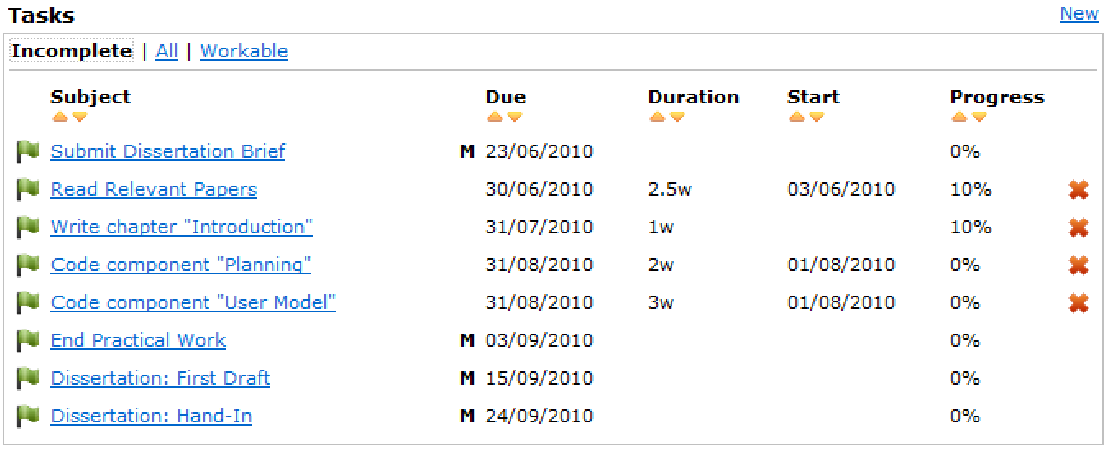


Figure 5.5.5: Project progress submission screen for students

be assigned to one of these special tasks in order to denote that they count towards this milestone. All task-related features are very similar to those used in the first experiment prototype (see section 4.2), however, without the option to create sub-tasks.

Pursuant to the monitoring scheme, students are assigned to a monitoring group, which forms a social space for all members within which they can communicate via group comments and replies, or by emailing their peers directly. Furthermore, group meetings are organised by their monitor and automatically included in the list of upcoming events for every group member. For monitors and supervisors of all students, a dashboard is provided on the group page; it provides simple performance indicators for each student, enabling staff to identify issues quickly.

To raise students' progress awareness and in order to enable them to compare their own progress against that of their peers, a ranking table is provided. A similar technique



Tasks New

Incomplete | All | Workable

Subject		Due	Duration	Start	Progress
Submit Dissertation Brief	M	23/06/2010			0%
Read Relevant Papers		30/06/2010	2.5w	03/06/2010	10%
Write chapter "Introduction"		31/07/2010	1w		10%
Code component "Planning"		31/08/2010	2w	01/08/2010	0%
Code component "User Model"		31/08/2010	3w	01/08/2010	0%
End Practical Work	M	03/09/2010			0%
Dissertation: First Draft	M	15/09/2010			0%
Dissertation: Hand-In	M	24/09/2010			0%

Figure 5.5.6: Task list on student project page; tasks marked with an "M" are milestone tasks

was used by Mochizuki et al. [2008] to raise team member awareness of task workloads and individual member progress in a project-based collaborative setting, reportedly encouraging each member to work on the tasks assigned to them. In the scope of a group, all group members are ranked, in other scopes the ranking is provided for all students studying on the same programme. A student's score v in this table is calculated using the variables in Table 5.3 for the current week such that

$$v = m + p + q_b + q_a + \frac{e_a}{e_t} \cdot 100 \tag{5.5.1}$$

where e_a is the number of attended events and e_t the total number of events of the student in the current week, so that $\frac{e_a}{e_t} \cdot 100$ yields the percentage of attended events. Also, progress feedback and event attendance is aggregated internally and visually presented in a series of charts and diagrams, making students aware of their progress in relation to that of the cohort (the average), and their performance over time. A list of charts provided in the system is listed in Table 5.4 and examples are depicted in Figure 5.5.7.

5.5.2 Structural System Design

In the next step, structural elements of the system were modelled using the use cases presented in section 5.5.1. These are (i) components and their interdependencies, and eventually (ii) classes representing concrete domain logic.

5.5.2.1 Components

Similar to the design used for the first experiment prototype (see section 4.3.2 on page 99), the system is based on a contract-driven and service-oriented approach, that is, components on different logical layers hold references to a set of interfaces rather than their

Table 5.4: Performance charts provided to system users

Chart	Description
Current week's performance	Four histograms showing the distribution of progress, motivation, and report quality ratings for the current week
Last week's performance	As current week's performance chart, but showing last week's rating distribution
Performance trend	A graph showing progress, motivation, and report quality ratings over time
Event attendance trend	A graph showing event attendance rates in percent over time
Quantitative report metrics trend	A graph showing the number of words in the body of the report and the number of pages in the appendix over time
Milestone progress	A bar chart depicting progress on each of the four milestone tasks in percent
Task statistics	A bar chart depicting the total, complete, incomplete, and overdue tasks (in absolute numbers)

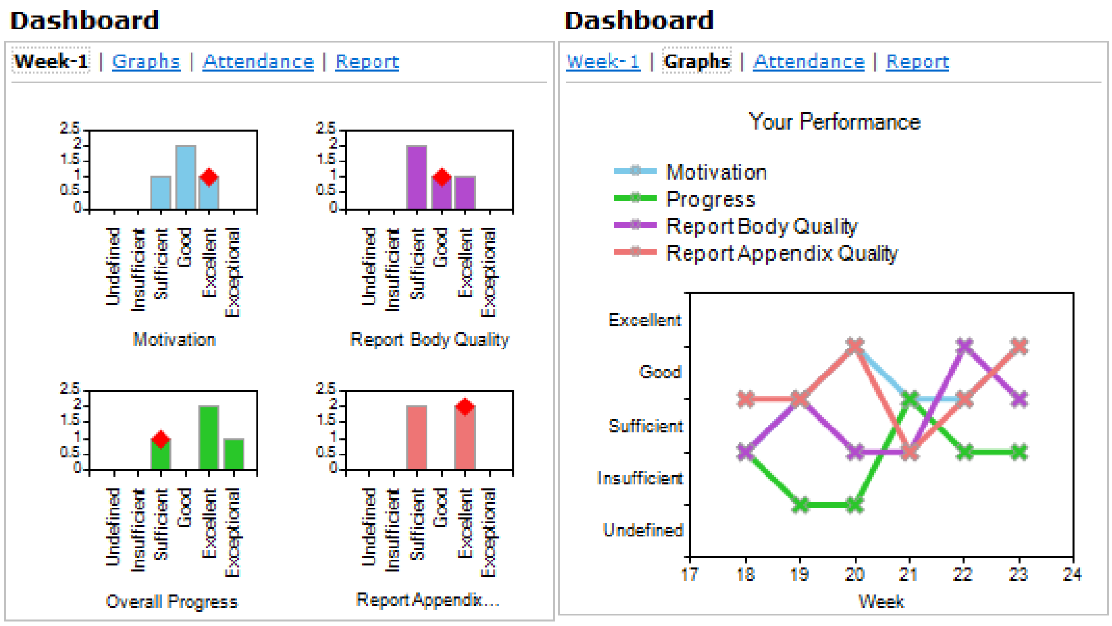


Figure 5.5.7: Examples of charts used for progress data visualisation

concrete implementation. This enables the implementation to be modified and distributed in different ways without affecting or breaking other components and – in particular – without rebuilding them because they are contained in separate assemblies. Furthermore, their deployment to different physical tiers is more flexible using this approach. The resulting component diagram is shown in Figure 5.5.8.

There are three logical layers, namely front-end (user interface), business logic, and data access. The front-end layer is made up by three different components, following the model-view-controller pattern. The views component contains dynamic web sites displaying model data, while the controller component controls (i) the sequence and

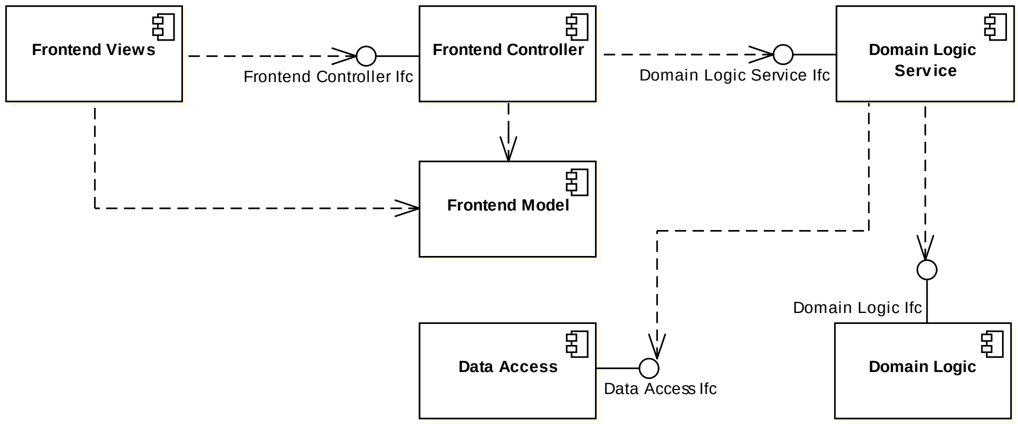


Figure 5.5.8: Component diagram

content of information displayed to the user on the view, (ii) access to business logic using the domain logic service interface, and (iii) how data retrieved from that component is mapped onto the model. The domain logic service is another service layer which is put on top of the actual domain logic, which is designed using a domain model approach [Fowler, 2002]. This means that rich domain classes with complex interdependencies and logic are used within the component, while these elements remain opaque to the outside world. In contrast, the domain logic service holds interfaces and methods for concrete calls associated with certain business use cases (see section 5.5.1), for example, submitting an overall progress rating for a particular student. In other words, the front-end layer never directly accesses the domain logic but uses the domain logic service instead. The advantage is that different services can be created for specific front-ends without changing the actual domain logic or any of their interfaces. Furthermore, data for domain classes is retrieved using the data access interface. The underlying component creates and populates domain objects upon which business logic is then performed.

5.5.2.2 Classes

The main component of the system is the domain logic component. Logically, it is divided into three packages/namespaces: `UserModel` (see Figure 5.5.9), `Management`, and `Common`. The `UserModel` package contains classes holding user and organisational unit-related data and functionality. The system supports different types of organisational unit: composite units such `Degree` and `Programme`. For example, "Master of Science" would be a degree, and "MSc in Software Engineering" a concrete programme of study belonging to that degree. In contrast, groups and projects are leaf units, that is, they are atomic and cannot contain any other units as their children. Users can be associated with many organisational units; this is modelled using the `Association` class, and every user has a particular role with regard to this association. Each user also has a global role in the system, for instance, student, supervisor, or monitor. This role is used in combination with unit user roles and a set of permissions to determine users' rights with regard to certain system features. When associating users with units, the system has to make sure that the following constraint is met: a student can only be associated with one project, in other words, for each user there is exactly one project association with the user's role in this association being "student". Furthermore, a user can be member of groups; groups and projects have to be attached to a parent unit, in most cases this is a degree.

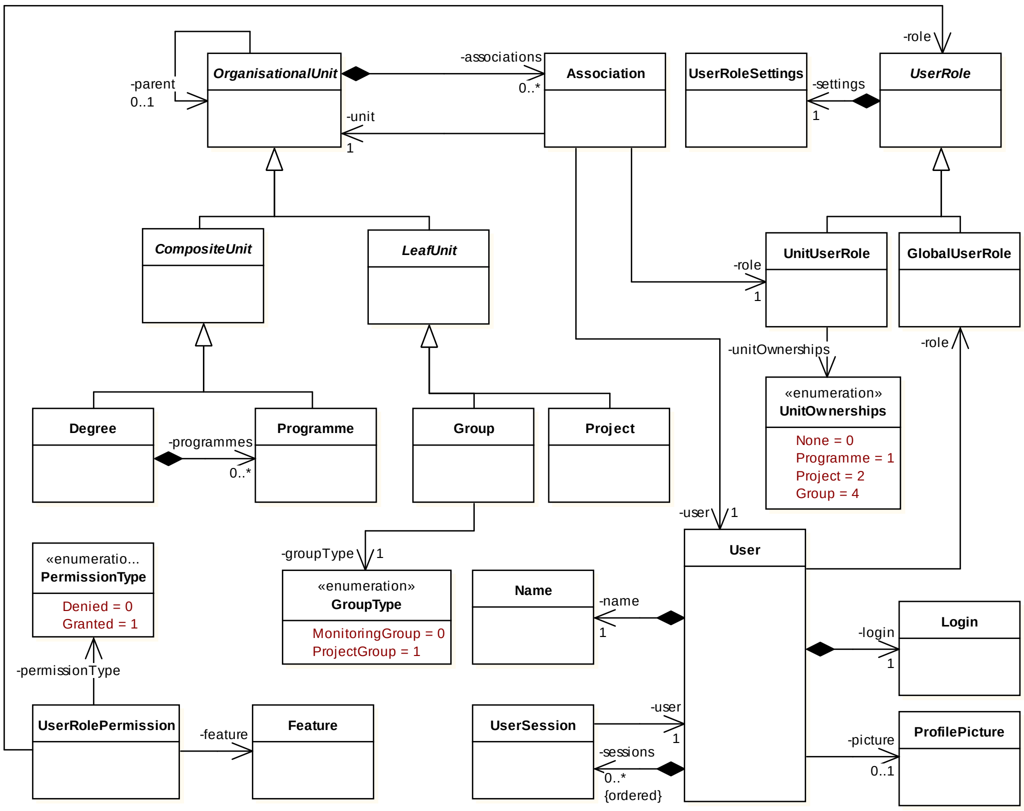


Figure 5.5.9: User model class diagram

The `Management` package (see Figure 5.5.10) contains classes dealing with project management features and data. Atomic items which can be planned are represented by a concrete implementation of `PlanningItem`, these are tasks, milestones, and events. Tasks can only be created within projects and hold an optional list of prerequisite tasks which must be completed before progress on the current task can be made. A task has a transient state represented as a colour code such as red (2), yellow (1), or green (0). This state s is determined at runtime using Algorithm 5.1 with t_d being the task's due date, Δt its planned duration in days, and p its progress in percent. Milestones are special tasks denoting the completion of a particular project stage. Optionally, regular tasks can be associated with a milestone to indicate that they count towards that project stage. Four milestones were predefined in each project:

1. Submit dissertation brief, outlining the project topic, deliverables, and intended outcomes

Algorithm 5.1 Task state determination

Ensure: $s \neq undefined$
  $s \leftarrow 0$
  if $t_d \neq undefined$ **then**
    if $\Delta t \neq undefined$ **then**
      $h = now + \Delta t \frac{100-p}{100}$
      if $h > t_d$ **then**
        $s \leftarrow 2$
      else if $(h+3) > t_d$ **then**
        $s \leftarrow 1$
      else
        $s \leftarrow 0$
      end if
    else
      if $(t_d - 1) \leq now$ **then**
        $s \leftarrow 2$
      else if $(t_d - 3) \leq now$ **then**
        $s \leftarrow 1$
      else
        $s \leftarrow 0$
      end if
    end if
  end if
  return s

2. End practical work: most projects involve a practical part which should be finished by a certain date to ensure that the student has enough time left to write their report.

3. First draft of dissertation

4. Dissertation hand-in

The second aspect of the management package is concerned with the organisation of events. Events can be created within leaf units, that is, either groups or projects. Recurring events are supported for the most common scenarios such as daily, weekly, monthly, and weekly recurrences; this feature has been re-used from the prototype of the first experiment and slightly optimised to cope with higher system load. Internally, the system works with instances of the interface `IEvent`, which can hold either a persistent event (stored in the database) or an event occurrence (an instance of an event recurrence). The latter is generated dynamically when a recurring event is retrieved from the database, that is, upon retrieval the system automatically expands the recurrence between a given start and end date by creating a set of `EventOccurrence` instances using a `RecurrenceExpander` algorithm, taking cancelled and changed occurrences into account. Furthermore, a set of participating users are associated with each event. Typically, when an event is created in a group, all group members are added to this set. Similarly, events created in a project will be associated with the student and their supervisor by default. Events defined in a group are automatically added to the project calendar of all students participating in the group event.

Finally, the package contains classes holding data and functionality for any kind of feedback submitted by users as part of the continuous progress reporting process pursuant to the monitoring scheme. There are two types of feedback: an event feedback instance refers to a user's attendance feedback to a particular event occurrence. Once an event has passed, this feedback is provided by students about their own attendance, and supervisors and monitors about the attendance of their students in project/group meetings. Conversely, weekly project progress feedback refers to the overall progress and motivation of a student as well as quantitative and qualitative feedback on their dissertation/report. Qualitative feedback is a rating ranging from 0 to 5 and can be provided by all users associated with a project, that is, student, supervisor, and monitor. A rating of 0 can only be submitted by supervisors or monitors and denotes "not seen", in other words, they did not see their student in the associated week. Before progress data is aggregated and used in rankings and/or performance charts, ratings are ranked dependent on who submitted them such that supervisor's feedback takes precedence over monitor's feedback, which again takes precedence over student's feedback.

Both the user model and management namespaces are dependent on some common classes contained in the `Common` package (see Figure 5.5.12). Firstly, there are classes holding note-related functionality: classes implementing `INoteContainer` can hold a set of attached notes and replies to these notes. In the current version of the system, notes can only be created within groups, therefore they are referred to as group comments or notes in the remainder of this work. Notes and other classes which implement the `ISecurable` interface can be protected by assigning visibility rules. There are three types of visibility rule: (i) a unit visibility rule enables all members of the assigned organisational unit to view the associated artefact, (ii) a user visibility rule expects a set of users who are able to access the artefact, and (iii) a private visibility rule declares the artefact as private and only enables their owner to view and access it.

Secondly, there are classes dealing with news feed data and functionality. Whenever a user performs a particular activity which is of interest to other associated users or the groups they are in, the system automatically creates a news feed entry. This entry of type `NewsFeedItem` contains a summary of the artefact upon which the activity was performed, its context, for example which unit it is contained in, and some information about the actor triggering the creation of the entry. The context and the activity itself determine the target users who will be notified of it. For example, an activity in a group will trigger all group members to be notified, whereas an activity within a project is only propagated to the users associated with that project, normally these are student, supervisor, and monitor. When reading items from the database, the specialisation `TargetedNewsFeedItem` is used instead. An example of a news feed is shown in Figure 5.5.11.

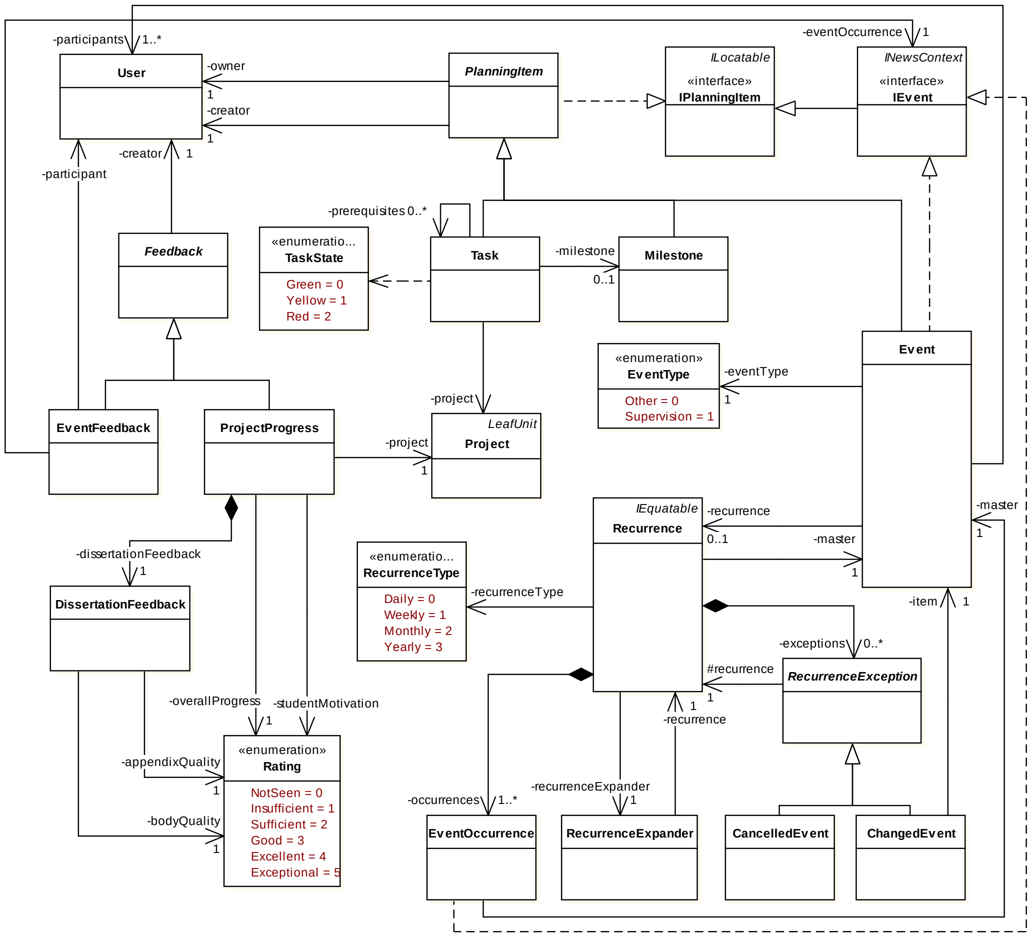


Figure 5.5.10: Project management class diagram

Thirdly and finally, the `Common` package implements certain cross-cutting concerns such as logging (`ActivityLogEntry`) as well as the representation of a calendar week and duration (in hours, days, or weeks). The activity log contains an entry for every user-system interaction and is used for analysis purposes.

5.5.3 System Architecture

The system was implemented using a three-layer architecture following the one presented in the context of the first experiment prototype (see Figure 4.3.8 on page 100). The three layers are user interface on the top-most level, business logic in the middle, and data access on the lowest level, whereby the latter communicates directly with the database. The user interface never makes calls to the data access layer but always to the business logic layer. In fact, the user interface has no knowledge of the data access layer service contract whatsoever. This basic concept was already outlined in section 5.5.2.1 and is enabled by using *object factories* in connection with interfaces.

In theory, this strict three-layer approach enables each layer to be deployed to a different physical tier/machine since all inter-layer communication is performed using interfaces

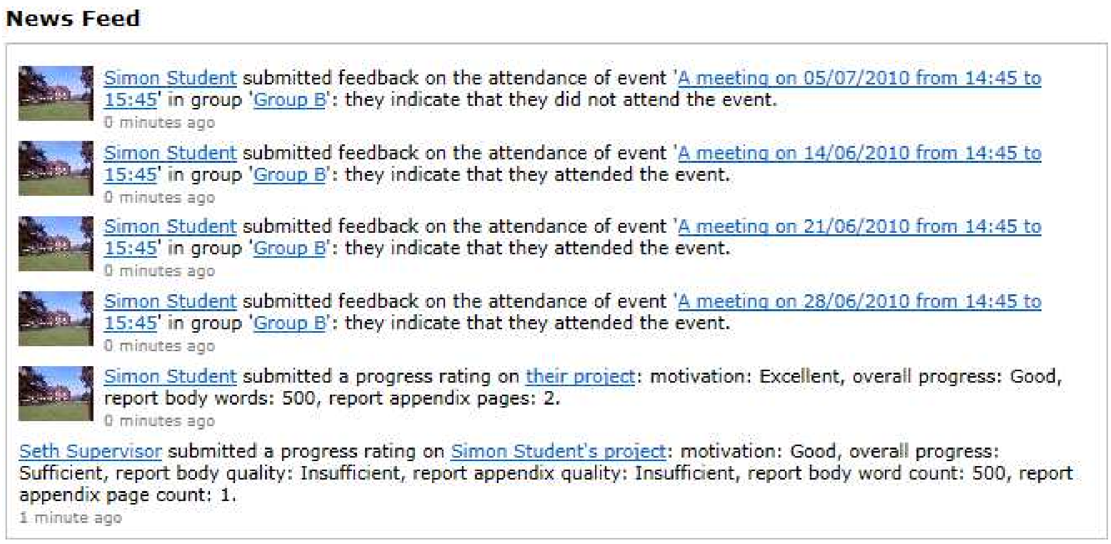


Figure 5.5.11: News feed

rather than concrete service implementations. At any given time, the object factory makes sure that the "correct" service implementation is instantiated (see Figure 5.5.13); this happens at runtime and is completely opaque to the caller. The factory decides based on an external configuration file which can be changed without re-compiling the application, enabling instantiation targets to be hot-switched at runtime without breaking the system. However, in the current version, all three layers were deployed to the same physical machine.

The whole system consists of two top-level applications: the actual web application and a background service which periodically sends out email notifications. Top-level in this context means that these applications are situated on the top-most layer; business and data access layer are shared between them. The background service uses a template-based design. Email templates are stored in the database and contain content place holder information which is later replaced by specific data, yielding a personalised email sent out to the user. There are seven email notification algorithms with one associated template each:

1. The **feedback algorithm** is used for reminding users that feedback is required on either weekly progress and/or event attendance. The notification routine is executed every 20 minutes and selects all past events with missing attendance feedback from one or more participating users. Simultaneously, it checks whether weekly progress feedback has been submitted and reminds all users associated with a student project to do so.

2. The **task algorithm** periodically checks for task state changes and reminds users if it finds such a change.

3. The **event algorithm** selects events which start in the next 24 hours and sends out an email reminder to all associated event participants.

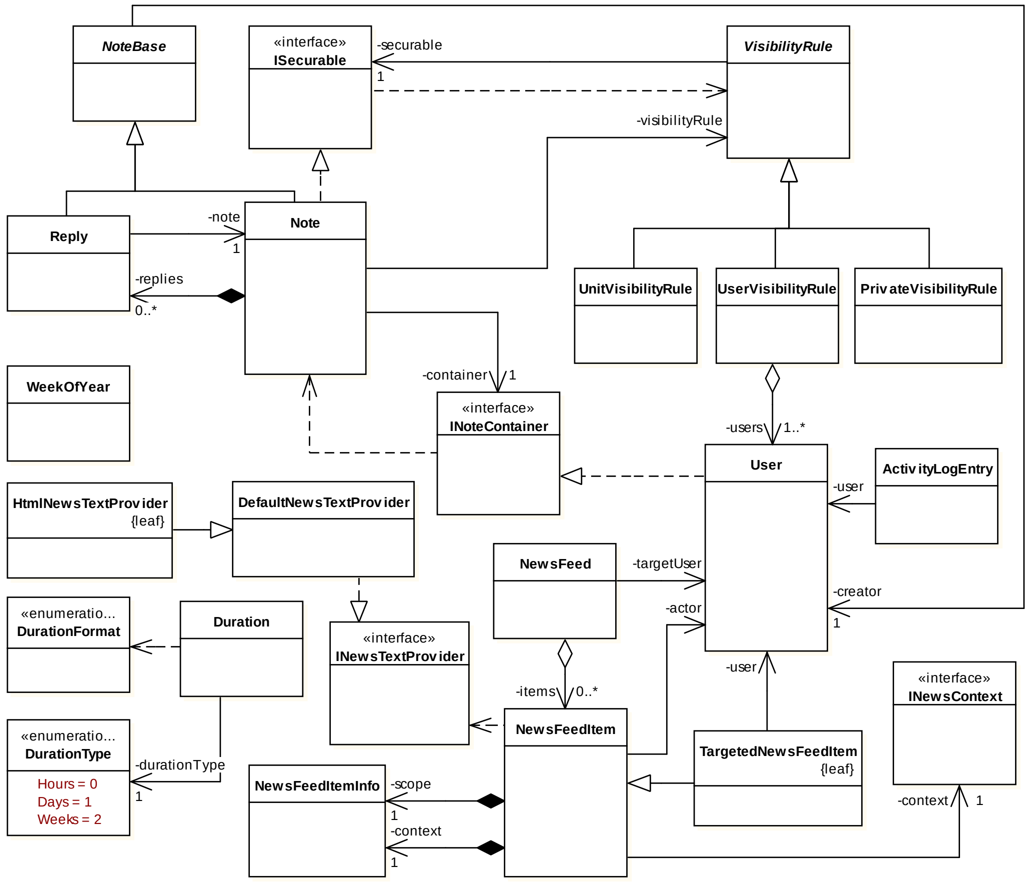


Figure 5.5.12: Common package class diagram

4. The **project algorithm** checks whether regular user activity occurs on student projects, for example, if tasks are updated regularly and if supervision meetings are present and up-to-date. If this is not the case, the student associated with the project is notified.

5. The **news feed algorithm** runs every 20 minutes and selects entries from the activity log which have occurred since the last check. It then determines who to notify which is dependent on the activity and the context in which it occurred.

6. The **follow-up algorithm** is aimed at detecting students who did not attend a series of consecutive meetings and reminding them that their attendance is required.

7. The **survey algorithm** is executed up to 3 times in 20 days at the end of the study and reminds students and/or monitors who have not yet filled in the online closing questionnaire.

5.5.4 Technology-Supported Learning Aspect Features

In section 2.7 on page 68, four technology-supported learning aspects (TSLAs) were introduced. In the system, these learning aspects correspond to one or more features;

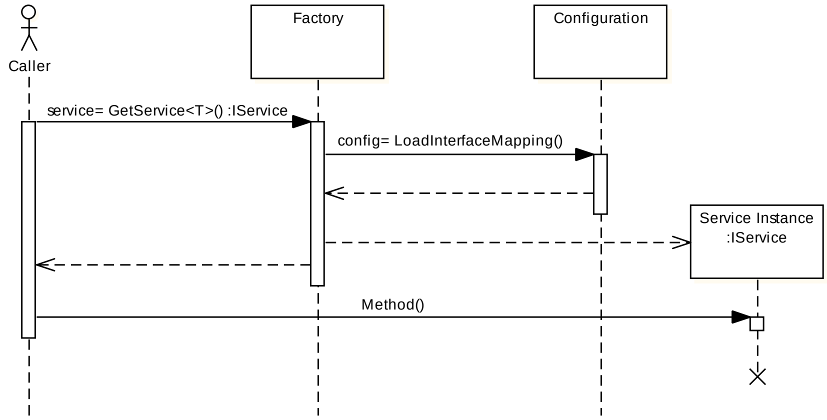


Figure 5.5.13: Service instantiation using object factories

this alignment is shown in Table 5.5.

Table 5.5: Technology-supported learning aspects (TSLAs) and corresponding system features

TSLA	System Feature(s)
Motivation	Progress and event feedback, visualisations (dashboard and charts), ranking table, email notifications
Time Management	Task list, event calendar, project page, group page
Progress Awareness	Visualisations (dashboard and charts), ranking table, news feed, email notifications
Monitoring	Progress and event feedback, comments on group pages

5.6 Research Methods

This section describes the analyses which were used on the data in order to establish evidence in favour of or against research hypotheses listed in section 5.3. They were conducted using version 18 of the PASW/SPSS Statistics package[2] on all quantitative and qualitative data collected during the study. First, the different types of data will be described, along with how they were merged into the final data set subject to analysis. Then, a brief outline on all statistical tests used in the analysis will be provided in section 5.6.3. Readers familiar with their theoretical background may skip these sections.

[2]http://www.spss.com

5.6.1 Data

The data set on which all statistical analyses were carried out was obtained by merging different types of data collected during the experiment. Before the analysis, all user-related personal data which could be used to identify individuals in the population was removed and replaced by a unique numerical case number, while the removed data was retained in a separate place. This is required pursuant to the Data Protection Act [UK Government, 1998] since any user has the right to access all data stored about them at all times. The resulting target data set is made up as follows:

1. System log data, in other words, all user activities on the system. This data contains (a) meta data on user-system interactions, and (b) the data resulting from these interactions. For example, if a user accessed any of the dashboard graphs or graphs, a system log entry representing that activity is created. Conversely, the progress feedback submitted by students, monitors, and supervisors is an example of data resulting from a user activity.

2. Quantitative and qualitative data was collected using questionnaires. For example, the closing questionnaire asked students and monitors to rate the helpfulness and motivational value of system features.

3. Qualitative data was collected during semi-structured interviews with students and monitors. This data was used to support the analysis, but not directly since it is difficult to encode numerically.

In all cases, transformations had to be applied before merging data into a single data set. For this purpose, Microsoft SQL Server Analysis Services (MSSQL-AS) and other techniques were used. MSSQL-AS provide features to (i) stage original data in an MSSQL server instance using projections, (ii) apply calculations on the staged data, (iii) define multi-dimensional cubes using facts and dimensions, and (iv) process the cube using on-line analytical processing (OLAP) queries. The resulting tabular data was then exported and imported into SPSS where it was eventually merged with existing data, using the unique case number assigned in the anonymisation process as a primary key.

5.6.2 Variables

The final data set contains about 719 variables. With regard to the hypotheses made in section 5.3, the following distinction is made:

- System use and all related data are *independent variables* in the analysis of the above hypotheses.

- Academic performance (marks), student success rate, perceived motivation, progress awareness, and project management capabilities are *dependent variables* in the analysis of the above hypotheses.

A detailed list of all variables can be found in Appendix C. Furthermore, Table 5.6 shows a summary of the most important variables, their type, and the number of associated variables; also refer to section 3.2 on page 82 for a list of possible variable types and their definition. Some of these variables will also be explained in the context of special analyses in the following sections.

Table 5.6: Summary of variables used in the analysis

Variable description & number of variables in the data set		Type
Final report metrics (body word count, appendix page count) submitted by student, monitor, and supervisor for each week	96	Scale
Final report quality metrics (rating between 0 and 5) submitted by monitor and supervisor for each week	96	Ordinal
Overall project progress and motivational state (rating between 0 and 5) submitted by student, monitor, and supervisor for each week	96	Ordinal
Average overall project progress and motivational state submitted by student, monitor, and supervisor for 4-week-blocks	24	Scale
System use, that is, user-system-interaction counts for each system feature	60	Scale
System use clusters established using cluster analysis	4	Nominal
System use of monitor and supervisor for each student	71	Scale
Late penalty (in days) on submission of dissertation brief, dissertation, and one assignment in the taught part of the MSc	3	Scale
Extensions granted on submission of certain deliverables	3	Nominal
Average overall progress and motivation for each role (student, monitor, supervisor)	6	Scale
Information about monitor and associations with programme of study etc. for each student	6	Nominal
Event-specific data, for instance, attendance rate, overall number of events on project/group level	3	Scale
Project task-specific data	4	Scale
Number of email notifications sent out by the system including their purpose	7	Scale
Student mark on the taught part of the MSc	1	Scale
Student mark on the dissertation	1	Scale
Factor scores established using factor analysis	19	Scale
Closing questionnaire items	37	Ordinal

5.6.3 Statistical Tests

This section provides some general background information about the statistical tests used in the analysis of the study data set. More detailed information can be found in [Field, 2009] which provides a comprehensive description of the most important tests and their applications. However, it is important to understand the basics of these tests before the results will be presented in Chapter 6.

5.6.3.1 Simple Statistics

These are descriptive statistics such as the frequency distribution (histogram), and simple statistical models such as the mean and associated statistics.

The graphical representation of the frequency distribution is a histogram. It can be obtained by taking the scores (or observations) of a variable in a data set – normally in ascending order – and plotting the frequency of each score occurrence in the data set on the y-axis. An example of a histogram is shown in Figure 6.2.1a on page 166. The histogram is useful for visually analysing data, in particular, for detecting problems and whether the data is normally distributed. Normally distributed data follows the Gaussian distribution

$$f(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

with $\mu = \bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$ being the mean, that is, the peak of the curve, and σ^2 the *variance* which measures the variation of individual values of the variable in question:

$$\sigma^2 = \frac{\sum (x_i - \mu)^2}{N-1}$$

In other words, the sum of squared errors $(x_i - \mu)$ is taken and divided by the degree of freedom $N-1$. Taking the square root of σ^2, one receives the *standard deviation* σ which is a more convenient measure using the same "unit" as the original observation. When talking about the standard deviation with regard to a particular sample, one often uses s instead of σ to denote it.

5.6.3.2 Fitting Statistical Models to Data

The mean is the simplest statistical model, and the previous section has listed some ways to tell how well variable scores fit to the mean, namely the variance, squared error, and standard deviation. However, one normally needs to make more general inferences from data samples, that is, findings which apply to one sample and are also valid for a different sample or possibly all existing samples. This requires a statistical model to not only fit to the sample but also the population from which the sample was taken. This can be measured using the *standard error*. Let H be the population and $S_i \subset H$ several samples taken from this population, then μ_{S_i} represents the mean of S_i and μ_H the mean of the population. However, the true mean of the population is usually unknown and therefore the estimated standard deviation of the population is used instead. This is based on the sample, so that the standard error is defined as $\sigma_{\bar{X}} = \frac{s}{\sqrt{N}}$ with s being the standard deviation of the sample and N the sample size. The standard error thus measures the variability of means (in experimental setups) or the variability of the correlation between variables (in observational setups). The higher the sample size the more accurate the standard error of the mean, meaning that the sample size has a significant influence on the population estimate. Its reliability is indicated by a *confidence interval*. It is established using z-scores of the original data with $z = \frac{X - \bar{X}}{s}$, that is, the original variable scores are converted so that the resulting data set has a mean of 0 and a standard deviation of 1. This is useful for establishing the probability of a particular variable score occurring in a particular distribution. Furthermore, 95% of all z-scores lie within -1.96 and 1.96, hence the confidence interval is defined as $\left[\bar{X} - (1.96 \cdot \sigma_{\bar{X}}), \bar{X} + (1.96 \cdot \sigma_{\bar{X}})\right]$. This can also be put as follows: given that one is interested in a population parameter and repeats a particular procedure (experiment or observation) multiple times and with multiple samples, the confidence interval is expected to include the population parameter 95% of the time.

When testing for an effect in a population, there are two types of mistake one can make:

- Type I error, also referred to as "false positive": one thinks there is an effect when there is in fact none, or in other words, one rejects the null-hypothesis H_0 when it is actually true. The probability of making a Type I error is denoted by α and also called the significance level. Most common values chosen for α are 0.05 (5%) and 0.01 (1%).
- Type II error, also referred to as "false negative": one thinks there is no effect when there is in fact one, that is, one accepts the null-hypothesis H_0 when it is actually false. The probability of making a Type II error is given as β.

The probabilities of α and β are interrelated such that if β increases α decreases, and vice versa. However, the exact nature of this relationship is complex. When quoting the result of a statistical test, one normally uses the significance value p denoting the probability of getting an effect in the sample if the null-hypothesis was true. If $0.01 < p \leq 0.05$ the effect is significant at the 0.05 level, if $p \leq 0.01$ the effect is significant at the 0.01 level, and otherwise ($p > 0.05$) the effect is non-significant.

One can also quantify an effect using the *effect size* r. It measures the importance and strength of a relationship between variables in the population. Suggested interpretations of r are: (i) low effect, describing 1% of the variance ($r = 0.1$), (ii) medium effect, describing 9% of the variance ($r = 0.3$), and (iii) high effect, describing 25% of the variance ($r = 0.5$).

5.6.3.3 Parametric vs. Non-Parametric Data

Many statistical tests make the assumption that the underlying data is parametric, they are *parametric tests*. These tests are based on a set of assumptions and valid results can only be expected if these assumptions are met:

1. The data is normally distributed, that is, the frequency distribution of the variable follows the normal distribution,

2. The data is homogeneous with regard to its variance, in other words, in case of several populations the variable must have the same variance across populations, and in case of correlations variances of all variables used in the test must be stable,

3. The data is measured at the interval level, which is normally the case,

4. The data is independent, either between groups, cases, or participant behaviours depending on the statistical test used.

Normality can be tested visually using a histogram or a P-P (probability-probability) plot. The latter depicts the degree to which two data sets – in this case the variable score distribution and the normal distribution – agree using the cumulative distribution function $F_X(x) = P(X \leq x)$. This function determines the probability of a random value X being less or equal to x. In practical terms, the P-P plot is achieved by (i) ranking and sorting the data, (ii) calculating the ranks' z-scores yielding the expected score values in the normal distribution, (iii) converting the data itself to z-scores, and (iv) plotting the latter against the expected z-scores established in the second step. The result visually shows how well the data fits to the normal distribution. When the data set is large, Q-Q plots are preferred over P-P plots. They are constructed by dividing the scores into quantiles, that is, into equal parts, so that not every single data point needs to be plotted. Q-Q plots can be interpreted in the same way as P-P plots.

Numerically, the normality of a variable can also be tested using the *Kolmogorov-Smirnov* test which measures the deviation between the variable distribution and the normal distribution. If the test yields a significant result ($p < 0.05$), the variable distribution has been found to be significantly different from the normal distribution, hence the data is *not* normal. Conversely, a non-significant result means that the data is normally distributed.

The data's homogeneity of variance can be tested using the *Levene's* test. It yields a significant result ($p \leq 0.05$) if the variances between populations or variables are significantly different and thus not homogeneous.

If the data is found to be non-parametric, there are three options. Firstly, one could visualise the data and look for outliers, namely variable scores which are significantly different from all other scores of the same variable, for example, surprisingly low or high [Field, 2009]. There are several ways of detecting outliers [Hodge and Austin, 2004]:

1. Visually, using a box or scatter plot, provided that the researcher knows the data and how to interpret it. In a box plot, outliers are typically shown as asterisks or circles outside of the upper and lower extreme on the y-axis. In a scatter plot, outliers can be detected by focussing on the values which are clearly outside of the main density area. While this method is easy to use, the choice between outlier and non-outlier often seems rather subjective.

2. Statistically, using z-scores for the variable in question, whereby outliers are those cases with $z \geq 3.29$. This method is only suitable for scale and ordinal variables with real numbers.

3. Statistically, using the interquartile range (IQR): the ordered data is divided into quartiles Q_1 to Q_3 whereby Q_1 is the lower, Q_2 the median, and Q_3 the upper quartile. The interquartile range IQR is then defined as $IQR = Q_3 - Q_1$. Then, a value x with $x < Q_1 - 1.5 \cdot IQR$ or $x > Q_3 + 1.5 \cdot IQR$ is considered an outlier.

Most of these detection algorithms assume that the underlying data (without the outliers) is normally distributed. There are also some detection algorithms which can be applied to data violating this assumption, however, their computation is regarded as being too "expensive".

Once found, outliers can be removed by eliminating the whole case from the data set, by transforming all data hoping that this will eliminate the outlier, or by changing the score. Alternatively, there are a number of statistical tests which do not make the assumption that the data is parametric. These tests normally work with ranked data, in other words, the data is ordered in ascending order and then assigned an incremental rank starting at 1. The statistical test is then applied to the ranks rather than the actual data. However, the necessity of applying only non-parametric tests to non-parametric data is discussed controversially. Norman [2010], for example, showed that most parametric tests are robust enough to cope with data that violates the above assumptions. In this work, non-parametric tests are used whenever the data is found to be non-parametric and – where appropriate and useful – the result of the parametric test carried out on the same data is also provided.

5.6.3.4 Correlation Tests

Correlation analysis is aimed at finding relationships between independent variables statistically by examining their *covariance* and *correlation coefficients*. It is recommended practice to look at a graphical representation of the data in question before applying correlation tests. The most suitable diagram for this purpose is the *scatter plot* which displays the values of two variables for each case in the data set on a coordinate system such that a dot represents a vector $(x, y)^T$ with x being the first and y the second variable. The distribution of dots in the plot allows the detection of extreme variable values (outliers) and gives a first impression of possible relationships between variables. Outliers should be eliminated before applying any statistical tests as they can lead to false or misleading results.

Earlier, the term *variance* was introduced. It is the degree to which the data of one variable deviates from the mean. When looking at relationships between two variables, one is interested in the coincidence of the variances of both variables. In other words, if the two variables are related positively or negatively, they behave in a similar or the opposite way with regard to their variances, respectively. This principle is referred to as the *covariance* of two variables which is defined as follows:

$$\operatorname{cov}(x, y) = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{N - 1}$$

Unfortunately, the covariance is not a standardised measure because it depends on the unit of measurement of the two variables x and y. The solution is to standardise measures by using the standard deviation of the two variables as a unit of measurement; this yields the *correlation coefficient*

$$r = \frac{\operatorname{cov}(x, y)}{s_x s_y}$$

with $r \in \mathbb{R}$, and s_x and s_y being the standard deviation of x and y, respectively. The correlation coefficient $r \in [-1, 1]$ also indicates the type of correlation: $0 < r \leq 1$ means that the variables are positively correlated, while $-1 \leq r < 0$ denotes that the variables are negatively correlated, that is, they deviate proportionally. It is therefore equivalent to the effect size. If one of the two variables x or y is binary, the true correlation coefficient is $r_b = \frac{r\sqrt{pq}}{c}$ with r being the original correlation coefficient, p the larger proportion and q the smaller proportion of variable cases, and c the ordinate of the normal distribution. Now, one still has to calculate the probability p for $r \neq 0$, in other words, the probability of the relationship being different from zero. This is done by obtaining a t-statistic from z, which yields the degree to which an estimated value is different from its real value and its standard error.

Consequently, the output of a correlation test is the correlation coefficient r and the probability p indicating the correlation significance. A probability $0.01 > p \leq 0.05$ indicates significance at the 0.05 level (95% confidence), sometimes also flagged with a single asterisk (*), while $p \leq 0.01$ denotes significance at the 0.01 level (99% confidence); this is often flagged with a double asterisk (**). The most common representatives of this type of test are the Pearson and the Spearman correlation test, whereby the former is used with parametric and the latter with non-parametric data. If the Spearman test is used, one usually uses r_s to denote the correlation coefficient.

5.6.3.5 Comparing Means and Repeated Measures

When looking for relationships between variables, one can test for differences between (a) different groups of people or (b) the same group of people being exposed to different conditions. When talking about differences, one actually refers to the grand mean of one or more variables. If only two means (the grand mean of one variable under two different conditions) are to be compared, one can use the *t-test*. There are two types of t-test, namely the dependent-means and the independent-means t-test. The former tests for differences between means using the same group of people while the latter examines the difference of two means between different groups of people. In other words, if one is interested in the difference between two different cohorts, one uses the independent-means t-test, and the dependent-means test otherwise. Both tests assume that the data is parametric.

The dependent-means t-test uses a measure

$$t = \frac{\bar{X} - \mu_X}{\frac{s}{\sqrt{N}}}$$

with $\bar{X}$ being the population mean, μ_X the differences one expects to find between populations, and $\frac{s}{\sqrt{N}}$ the standard error of these differences. The value of μ_X is set to 0 if one assumes that there is no difference, that is, the null-hypothesis is tested. Conversely, the independent-means t-test looks for differences between two different populations, thus

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\left(\frac{s_1^2}{N_1} + \frac{s_2^2}{N_2}\right)}}$$

If the t-test is significant, the resulting value of t and the degrees of freedom df can be used to determine the effect size $r = \sqrt{\frac{t^2}{t^2+df}}$, which indicates whether the difference between the means is substantial or not.

In case there are more than two means to be compared, one uses a different statistical test, namely the analysis of variance (ANOVA). The reason behind this choice is simple: if one simply conducted a t-test for each possible combination of the n means (with $n > 2$), the probability of not rejecting the null-hypothesis while it is actually true is 0.95^n which is invariably smaller than 0.95. The probability of falsely rejecting the null-hypothesis (Type I error) is $1 - 0.95^n$, and if $0.95^n < 0.95$ this probability becomes $1 - 0.95^n > 0.05$, in other words, it is now more than 5%. ANOVA mitigates this problem by comparing two or more sample means and producing an F-ratio – the ratio of systematic variance to unsystematic variance. As the t-test, ANOVA is a parametric test and the data must meet the corresponding requirements. Furthermore, it assumes that the variables used in the test are independent.

If existing differences in the means of different measures (variables) obtained under different experimental conditions but in the same group of participants are examined, a repeated measures ANOVA must be used. The underlying principle is an analysis of variance (ANOVA) which compares more than two means under the assumption that the same participants are used. However, the repeated measures design means that the assumptions of independent variables is violated and the resulting ANOVA F-ratio will not be accurate. Therefore, one makes the additional assumption that the degree of dependency between different conditions is very similar. This assumption is called the *assumption of sphericity* which is tested using the Mauchly's test. It evaluates the variances of the differences between conditions and is significant ($p \leq 0.05$) if the assumption of sphericity is violated. In that case, the degrees of freedom used to obtain the F-ratio must be corrected following the methods of Greenhouse and Geisser or Huynh and Feldt. Applying these methods produces a corrected F-value and significance probability p.

In cases where means of non-normally distributed data are to be compared, non-parametric test should be used instead of those mentioned above. These tests operate on ranked data, that is, all values are first sorted in ascending order and assigned an incremental rank starting with 1. The statistical tests are then applied on the ranked and not the original data.

- The Mann-Whitney test or the Wilcoxon rank-sum test are used for comparing means of two variables (conditions) from two different groups of participants. These tests are equivalent to the independent t-test explained earlier. If more than two means of different groups need to be compared, the Kruskal-Wallis test is used.
- The Wilcoxon signed-rank test is used for comparing means of two variables (conditions) from two related groups of participants. This test is the equivalent of the dependent t-test for parametric data. In case more than two means of related groups are to be compared, Friedman's ANOVA test is used; this is equivalent to the ANOVA test for parametric data.

5.6.3.6 Factor and Principal Component Analysis

Sometimes a data set can contain so-called *latent variables*. These are variables which are made up by one or more existing collinear variables in the data set. Their combination is then called a "factor" or "component". Therefore, factor analysis and principal component analysis (PCA) are both aimed at finding relevant factors (= latent variables) in the data set, thereby reducing its size and supporting the researcher in identifying existing factors. It is based on correlations between input variables in an R-matrix, whereby variables with similarly large correlation coefficients make up the factors. Each factor is then assigned a score obtained using the scores of the underlying variables with regard to the case. Using these scores, further analyses, for example correlation tests, can be carried out with factors rather than with the original variables.

Both factor and principal component analysis are based on linear models. A factor analysis constructs a mathematical linear model from an underlying set of correlating variables and uses this model to identify factors. Conversely, PCA decomposes factors using eigenvalues of the underlying variable correlation matrix. The eigenvalues denote the relative importance of the factor and are also used to calculate eigenvectors indicating the loadings of individual variables on that factor. Following Kaiser's criterion, factors with eigenvalues greater than 1 are normally retained. If the analysis has fewer than 30 input variables, this criterion is considered too strict and it is recommended to retain factors with eigenvalues greater than 0.7 instead.

Typically, the result of a factor analysis or PCA is a table containing the factor loadings of all input variables. Since these loadings denote the importance of the variable with regard to the factor, they can be used to identify which variable is part of which factor. Sometimes, the interpretation of these loadings can be difficult, especially because some variables may load well on multiple factors. This can be mitigated using factor rotation, that is, let a factor be a vector or axis along which variables are plotted, then the loading of variables on that factor can be maximised by rotating that vector. There are different rotation algorithms, for example, the Quartimax rotation is aimed at maximising factor loadings of variables on as few factors as possible, while the Varimax rotation attempts to do the opposite.

Chapter 6

Results and Discussion

This chapter gives a detailed outline of all results obtained from statistical analysis. Firstly, descriptive statistics of the main variables are presented to give the reader an insight into the data. Secondly, test results regarding the four main research hypotheses (see section 4.1 on page 89) are covered. Thirdly, other interesting results not directly related to the main hypotheses are summarised. They give further insights and are indirectly relevant to the study. The chapter then concludes with a thorough discussion of all results.

6.1 Descriptive Statistics

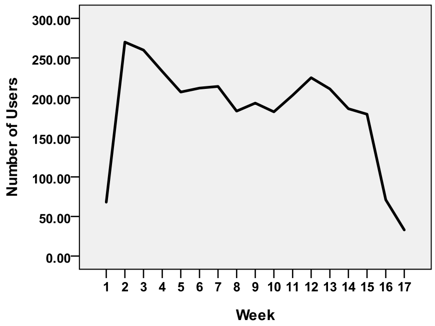
Before focussing on relationships between variables in the data, hence examining the hypotheses made in section 5.3, it is helpful to look at some descriptive statistics, mainly graphs and frequency listings of some important variables. Besides visualising the data, this also facilitates the use of the appropriate statistical test for further analysis.

6.1.1 System Use

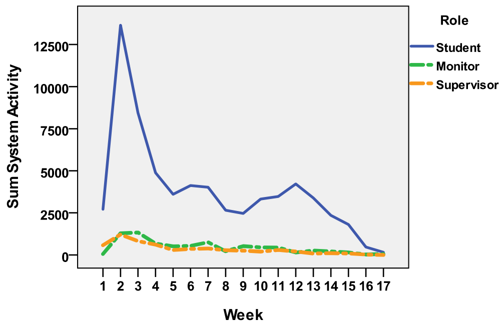
System use is the total number of user-system interactions over a period of 17 weeks. The term is used synonymously with others such as "activity count" or "system activity" in this report. The variable is significantly different from the normal distribution (Kolmogorov-Smirnov $D(272) = 0.160$, $p < 0.01$) with mean $\mu = 241.99$ and standard error $\sigma = 14.75$.

The total number of active system users over time is shown in Figure 6.1.1a. Most users were online in the second week, just after the system had been launched for general use. After week 2 there is a slight downward trend with several lows in weeks 8, 10, and 15, and an intermediate spike in week 12.

System use by role over the 17-week period is depicted in Figure 6.1.1b, whereby role refers to students, monitors, or supervisors. There was a spike of student activity on the



(a) Number of active system users



(b) Sum of system interactions by role

Figure 6.1.1: System use charts over 17 weeks

system between weeks 2 and 4, followed by a sharp drop and two intermediate spikes in weeks 6 and 12. The last two weeks were shortly before and after the dissertation submission deadline and many monitoring meetings did not take place during that time, hence the sharp drop in activity. It is also noteworthy that student activity was significantly higher than monitor and supervisor activity. While monitor activity generally follows that of students but on a lower level, supervisor activity was nearly constant and then slightly decreasing from week 2 onwards, but mostly staying below monitor activity.

On average, all users made $\frac{\mu}{17} = \frac{241.99}{17} = 14.23$ interactions with the system per week. Looking at system use by role, monitors ($N = 18$) used the system most frequently with $\mu = 426.56$ and 25.09 interactions per week, followed by students ($N = 235$) with $\mu = 267.91$ and 15.76 interactions per week, and finally supervisors ($N = 60$) with $\mu = 97.53$ and 5.74 interactions per week on average.

In terms of features (see Figure 6.1.2), the majority of student-system interactions (27.26%) occurred on the current week's performance histogram chart, followed by the home page including ranking table and progress feedback prompt (13.33%), the student project page (8.67%), user logins (8.54%), user profile pages (7.84%), last week's performance histogram (6.77%), and monitoring group pages (6.3%). All other features received considerably lower hit counts. The least-used feature was group comments with only 0.09% of hits.

Figure 6.1.3 shows the number of users who used any of the features at any given time during the 17-week period. Of 378 total system users, the majority (358) used charts and graphs visualising student performance metrics, followed by the system home page (343 users), the project page (335 users), and user profiles (330 users). Only a minority of users (47) used the group notes feature.

Passive usage data needs to be contrasted with actual numbers of artefacts representing the corresponding feature. For example, task list usage can occur passively (users browse the list of existing tasks without making changes to them) and actively (users create and make actual changes to tasks). Therefore, the analysis of artefact numbers is important

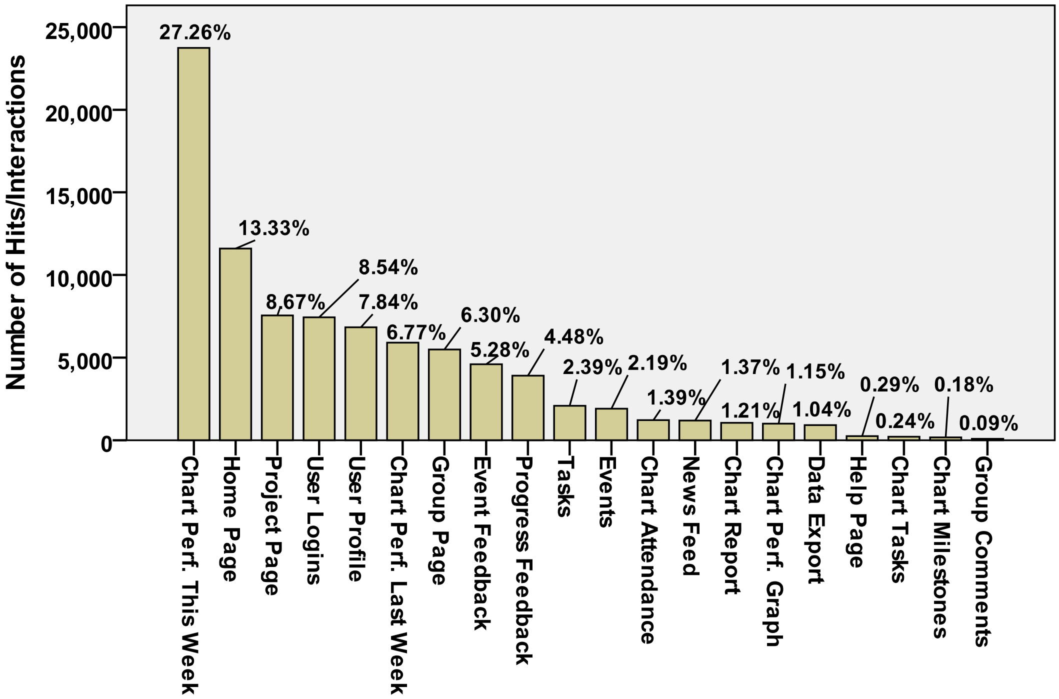


Figure 6.1.2: Feature use in number of interactions

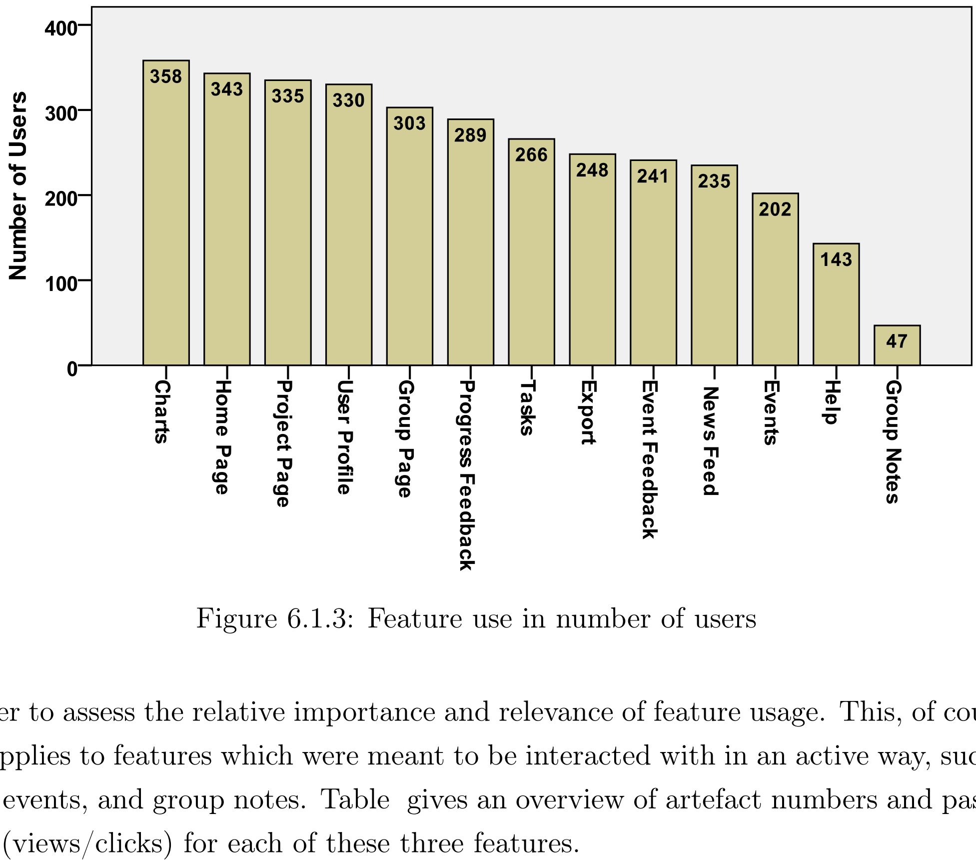


Figure 6.1.3: Feature use in number of users

in order to assess the relative importance and relevance of feature usage. This, of course, only applies to features which were meant to be interacted with in an active way, such as tasks, events, and group notes. Table gives an overview of artefact numbers and passive usage (views/clicks) for each of these three features.

The table lists average numbers of tasks, events, and group comments per user and contrasts these numbers with the number of passive interactions made with any of these artefacts. Task numbers should be regarded as a special case. As mentioned earlier, the

Table 6.1: Number of tasks, events, and group comments contrasted with passive interactions

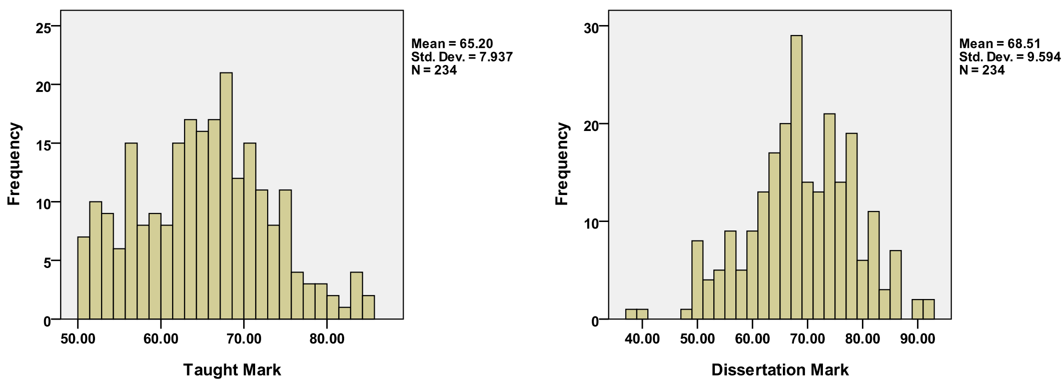
Feature	Numbers						Passive Use	
	Average Per User				Total			
	Total	Own	Monitor	Supervisor	Min	Max	Hits	Users
Tasks	4.54	4.30	0.00	0.24	3	17	1184	266
Events	1.31	0.91	7.37	1.32	1	74	763	202
Group Comments	0.22	0.21	1.05	0.06	1	36	68	47

system automatically generated 4 milestone tasks for each student at the beginning of the project phase; these tasks could not be deleted from the task list. One supervisor requested one of these milestones to be removed from his students' list, explaining the minimum of 3. This means that on average, students only created 0.3 tasks beyond pre-defined milestones, which is a very small number. The maximum number of managed task in a project is 17.

In contrast, the events feature was predominantly used by monitors to manage monitoring meetings in their group(s) and supervisors to manage supervision meetings. Similarly, group comments were most used by monitors to make announcements or provide clarifications outside of meeting hours.

6.1.2 Student Performance

Student performance is made up by two objective measures, namely the taught mark before the start (pre-test) and the dissertation mark at the end (post-test) of the MSc summer project. Both variables are normally distributed; the Kolmogorov-Smirnov test yields $D(234) = 0.047$ with $p > 0.05$ for the taught and $D(234) = 0.046$ with $p > 0.05$ for the dissertation mark. Histograms of both measures are shown in Figure 6.1.4.



(a) Taught mark (b) Dissertation mark

Figure 6.1.4: Student mark distributions (histograms)

The figure also shows that the mean dissertation mark was slightly higher than the mean taught mark with 68.99 compared to 65.76. A dependent t-test comparing both means reveals that the mean difference of 3.23 grade points is in fact significant ($t(273) = -6.881$, $p < 0.01$, $r = 0.458$), in other words, the mean dissertation mark was significantly higher than the mean taught mark. This is in line with findings for the previous year 2009 ($t(142) = -5.849$, $p < 0.01$, $r = 0.563$) with a mean difference of 3.68.

6.1.3 Progress Ratings

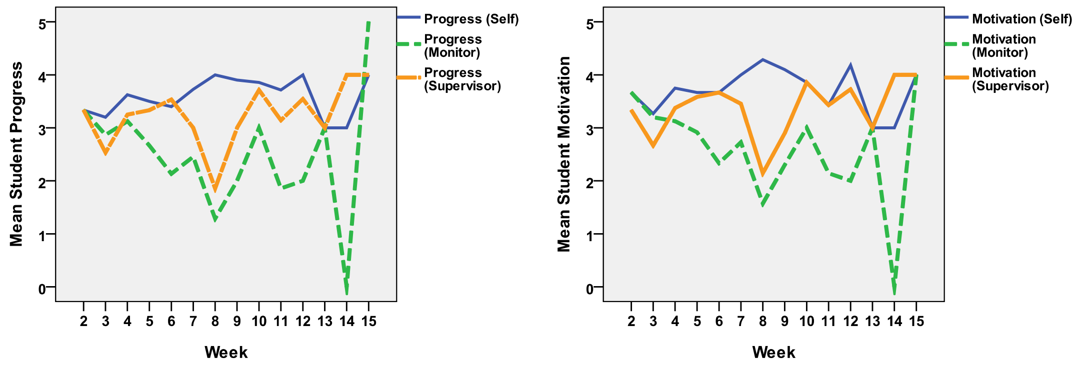
Progress ratings were submitted by students themselves, their monitors, and supervisors on a weekly basis and comprise (1) the overall student progress on the project, (2) their motivation, optionally (3) the number of words in their report body, (4) the number of pages in the report appendix, (5) the quality of their report body and (6) appendix. The latter two ratings could only be submitted by monitors and supervisors. Progress, motivation, and quality metrics were submitted on a scale ranging from 0 (not seen) to 5 (exceptional). Depending on the role of the user submitting each rating, the corresponding variables are distributed differently as shown in Table 6.2. In the table, μ denotes the mean and σ the standard error; the result of the Kolmogorov-Smirnov test for normality is also provided. Report quality and quantity ratings are not included here on the grounds that they contain too many missing values, especially because students started writing their report sooner or later depending on their individual project.

Table 6.2: Distributions of overall student progress and student motivation ratings

			Kolmogorov-Smirnov Test			
Variable	μ	σ	D	df	p	Distribution
Self-rated mean progress	3.20	0.09	0.126	78	0.004	Non-normal
Monitor-rated mean progress	2.29	0.12	0.099	78	0.054	Normal
Supervisor-rated mean progress	2.80	0.10	0.157	78	0.000	Non-normal
Self-rated mean motivation	3.44	0.09	0.105	78	0.034	Non-normal
Monitor-rated mean motivation	2.57	0.13	0.146	78	0.000	
Supervisor-rated mean motivation	3.10	0.10	0.158	78	0.000	

Plotting the mean student progress and motivation over the duration of 15 weeks (the first and the last two weeks have been omitted because users did not provide meaningful data during that time), one receives the graphs depicted in Figure 6.1.5.

Both graphs are very similar, suggesting that progress and motivation are interrelated irrespective of the submitting user's role. Most of the time, supervisor progress and motivation ratings remained below those submitted by the student themselves, and monitor ratings were in turn lower than those of supervisors. Interestingly, both monitors and supervisors reported a sharp drop in both overall student progress and motivation in the eighth week, while students themselves reported increasing values.



(a) Student overall progress

(b) Student motivation

Figure 6.1.5: Student progress and motivation rated by students, monitors, and supervisors over 15 weeks

6.1.4 Subjective Student Feedback

As mentioned earlier, students were asked to take part in a closing survey, containing questions about the perceived motivational effect of system features, their helpfulness for MSc project management, and users' agreement with general statements. What is more, they were asked to rate each of the dashboard charts with regard to its helpfulness for instigating progress awareness. Finally, users were enabled to submit a free-text comment or suggestion as for how to improve the system and make it more useful in the future.

It is common practice to conduct a reliability analysis on any questionnaire used in a study. Reliability analysis attempts to verify that individual questionnaire items remain consistent regarding what is measured by the questionnaire, in other words, if a set of questionnaire items is about the motivational effect of features, then a user who scores high on the set should also score high on randomly chosen individual items within that set. In practice, a method called *split-half reliability* is used to test this. It splits the data into two equal parts and calculates a score per part for each person who took the survey. If both scores are the same or very similar, one assumes a good scale reliability. This is measured using a correlation test between the two halves; if the correlation is strong this indicates a high reliability. Obviously, this method is dependent on the way of splitting the data, and hence the correlation test result might be biased. Another more common method is *Cronbach's alpha* test which is roughly equal to the split-half method. It comes up with an α-value indicating the scale reliability. Values greater than 0.7 for α are acceptable, assuming a high reliability.

Taking a conservative approach, both methods were used on all closing questionnaire items which were to be answered using a 5 or 6-point scale. Since different parts of the questionnaire measure different things, a separate analysis was performed on each survey part. The test results are shown in Table 6.3.

Table 6.3: Survey reliability analysis results

				Split-Half Method	
Category	Valid Cases	Items	Cronbach's α	Items per Half	r
Motivational effect of features	104	10	0.919	5, 5	0.798
Helpfulness for MSc Project Management	77	11	0.949	6, 5	0.889
Chart helpfulness for progress awareness	104	6	0.966	3, 3	0.893
Agreement with general statements	104	8	0.946	4, 4	0.839

The table shows a very high α-value ($\alpha > 0.9$) as a result of Cronbach's alpha test, and a very high correlation coefficient ($r > 0.7$) between the two halves used in the split-half method. This indicates that all items have a very high scale reliability.

6.1.4.1 Motivational Effect of System Features

The first part of the questionnaire was about the perceived motivational effect of certain system features. Students were asked to submit a rating from 0 to 5 on each questionnaire item, whereby 0 denotes "did not use", and $[1, 5]$ ranges from "did not motivate at all" to "motivated very much". There were $N = 104$ valid cases for each item, that is, 104 students answered all 10 items of this questionnaire part. The results are shown in Table 6.4, whereby the maximum percentage per item is underlined.

Table 6.4: Motivational effect of system features

			Percentage %					
#	Feature	Mean	0	1	2	3	4	5
1	Dashboard and charts	2.84	5.8	15.4	14.4	<u>27.9</u>	26.9	9.6
2	Ranking table	2.93	5.8	13.5	17.3	<u>26.9</u>	18.3	18.3
3	News feed	2.87	5.8	13.5	17.3	<u>27.9</u>	23.1	12.5
4	Email notifications	3.43	1.0	9.6	10.6	24.0	<u>33.7</u>	21.2
5	Self-reported progress	3.38	1.9	12.5	7.7	22.1	<u>35.6</u>	20.2
6	Monitor-reported progress	3.54	7.7	6.7	3.8	20.2	28.8	<u>32.7</u>
7	Supervisor-reported progress	3.61	5.8	7.7	2.9	19.2	<u>32.7</u>	31.7
8	Event attendance feedback	3.47	2.9	11.5	6.7	20.2	<u>31.7</u>	26.9
9	Task list	3.16	2.9	14.4	9.6	25.0	<u>32.7</u>	15.4
10	Comments on group pages	2.82	7.7	14.4	12.5	<u>31.7</u>	21.2	12.5

Of all 104 students who provided answers to these items, 32.7% percent think that monitor-rated student progress was motivating, followed by self-reported progress (35.6%), email notifications (33.7%), and supervisor-rated progress as well as the task list on the project page (32.7%). Surprisingly, the ranking table was one of the features perceived least motivating with only 36.6% of students rating it motivating or very motivating. The least used feature was group page comments, while email notifications were used by most users.

6.1.4.2 Feature Helpfulness for MSc Project Management

In the second questionnaire part, students were asked to rate the helpfulness of features for managing their MSc project. Again, answers could be chosen from a scale ranging from 0 to 5 with 0 denoting "did not use", 1 indicating "not helpful at all" and 5 meaning "extremely helpful". There were between 96 and 104 valid cases depending on the item, that is, some students did not provide an answer to some of them. The results are shown in Table 6.5.

Table 6.5: Feature helpfulness for MSc project management

				Percentage %					
#	Feature	N	Mean	0	1	2	3	4	5
1	Dashboard and charts	96	2.87	3.1	15.6	18.8	27.1	24.0	11.5
2	Ranking table	97	2.89	2.1	20.6	14.4	26.8	21.6	14.4
3	News feed	98	2.92	3.1	15.3	18.4	24.5	27.6	11.2
4	Email notifications	102	3.36	0.0	8.8	14.7	27.5	29.4	19.6
5	Monitor-rated progress	96	3.48	3.1	8.3	11.5	20.8	27.1	29.2
6	Supervisor-rated progress	97	3.78	2.1	7.2	4.1	20.6	28.9	37.1
7	Event attendance feedback	100	3.62	1.0	9.0	6.0	24.0	31.0	29.0
8	Task list	101	3.30	2.0	6.9	14.9	26.7	34.7	14.9
9	Event organisation	104	3.38	1.9	5.8	10.6	32.7	31.7	17.3
10	Data export	104	2.87	7.7	14.4	11.5	29.8	23.1	13.5
11	Comments on group pages	96	3.17	3.1	10.4	15.6	27.1	25.0	18.8

Features perceived most helpful for MSc project management were monitor-rated and supervisor-rated student progress feedback with 29.2% and 37.1% of students assigning the highest helpfulness rating, respectively. Again, the ranking table was not perceived useful; 35% of respondents rated this feature less helpful or not helpful at all. Finally, a majority of respondents were undecided regarding the helpfulness of the data export feature.

6.1.4.3 Chart Helpfulness for Progress Awareness

The third part was about perceived helpfulness of various charts displayed on the system in terms of if and to what extend they managed to support students' awareness for their own progress compared to others. There were $N = 104$ valid responses for all 6 items in this category, whereby answers could be chosen from a 6-point scale ranging from 0 to 5 with 0 denoting "did not use", 1 indicating "not helpful at all", and 5 "extremely helpful". Table 6.6 shows the result.

Table 6.6: Chart helpfulness for progress awareness

			Percentage %					
#	Chart	Mean	0	1	2	3	4	5
1	Weekly ratings histogram	2.73	5.8	17.3	18.3	26.9	20.2	11.5
2	Weekly ratings over time	2.68	9.6	14.4	18.3	24.0	23.1	10.6
3	Event attendance over time	2.74	8.7	14.4	17.3	26.0	21.2	12.5
4	Report metrics	2.72	11.5	10.6	18.3	22.1	28.8	8.7
5	Milestone task progress	2.83	7.7	11.5	17.3	26.9	26.9	9.6
6	Task progress	2.84	7.7	11.5	19.2	24.0	26.0	11.5

Proportionally, the report metrics, milestone task progress, and task progress charts were rated most helpful for increasing progress awareness with 28.8%, 26.9%, and 26.0% of users assigning the second-highest rating to these charts, respectively. For all other charts, users were mostly neutral regarding their helpfulness. The least used chart was the report metrics graph plotting weekly report quantity metrics, possibly because most users did not give accurate feedback on these metrics and generally started writing relatively late into their project.

6.1.4.4 Agreement with General Statements

In the final part of the questionnaire, a number of statements concerning student use of the monitoring system and MSc project management in general was provided. Students could rate each of these statements on a 5-point Likert scale from 1 to 5, whereby 1 denotes "do not agree at all" and 5 "fully agree". A total of 104 student provided valid responses to these items. Furthermore, students were asked to give feedback on the frequency of meetings with their monitor. This could be done on a scale from 0 to 5, namely "N/A" (0), "never" (1), "when I needed to" (2), "about every third week" (3), "about every second week" (4), "every week" (5). Students' feedback to general statements is listed in Table 6.7.

Feedback on the general helpfulness of the system and the monitoring scheme was mixed. The majority of students found that monitoring meetings helped them, however, they were neutral with regard to the monitoring system enhancing their project management, the helpfulness of the system for keeping them organised, communicating problems, and keeping contact with their monitor and/or supervisor. Most students also found that their monitor and/or supervisor picked them up on progress reports submitted on the system. Furthermore, they agreed on the system raising their progress awareness and enabling them to compare themselves with their peers. On the other hand, peer-to-peer communication was not something they found facilitated by the system, and in fact no special features for this purpose were provided.

Regarding the frequency of monitoring meetings, the majority of students (54.8%) indicated that they met with their monitor every week, followed by "when I needed to"

Table 6.7: Agreement with general statements

			Percentage %				
#	Statement	Mean	1	2	3	4	5
1	Found monitoring meetings helpful	3.74	12.5	3.8	19.2	26.0	38.5
2	Monitor/supervisor picked me up on my progress reports	3.41	13.5	9.6	23.1	29.8	24.0
3	System raised my progress awareness	3.34	13.5	12.5	24.0	26.9	23.1
4	System helped me keep myself organised	3.13	17.3	10.6	29.8	26.0	16.3
5	System helped me communicate problems to my monitor/supervisor	2.93	26.0	10.6	26.0	19.2	18.3
6	System helped me keep in contact with monitor/supervisor during absence	2.85	26.0	12.5	27.9	18.3	15.4
7	System enabled me to contact other students	2.63	32.7	14.4	24.0	15.4	13.5
8	System enhanced my MSc project management	3.09	13.5	19.2	28.8	22.1	16.3

(14.4%) which is equivalent with attending meetings in irregular intervals, and "about every second week" (9.6%). Only 3.8% of students admitted they never met their monitor.

6.1.4.5 General Feedback

Part of the general feedback students submitted was whether any other online or offline tools besides the MSc Monitoring System were used for MSc project management. Furthermore, they could submit a free-text comment on how to improve the system and make it more useful. In total, there were 63 valid responses to either part of the general feedback category, this is about 57% of all 110 users participating in the survey.

The most popular response (17.4%) was the use of Microsoft Project and a paper-based log book for project management, closely followed by other paper-based tools (12.7%) and Google Calendar (11.1%). Less used tools were Microsoft Outlook (6.3%), Microsoft OneNote (4.8%), Microsoft Visio, Apple iCal, and Notepad (3.2% each). Moodle, private Wikis, Subversion, Evernote, and Microsoft Word were rarely used with only 1.6% of respondents mentioning them in their answers.

Regarding suggestions for system improvement, 10 out of 63 respondents (15.9%) explicitly wanted the system to be continued, compared to 5 respondents (7.9%) who did not find the system useful at all and recommended it to be discontinued. Main user critique was that both system navigation and user interface need improvement (11.1% and 9.5%, respectively). Furthermore, 6.3% of respondents suggested to provide more interactive tools enabling user-to-user communication on the platform and improved charts/graphs; one user even requested an online chat feature. A few users (3.2%) complained about the number of emails they received from the system and recommended to reduce this to an absolute minimum. Online storage space for personal notes and files as well as compulsory system use for all participants were also suggested.

6.1.4.6 Feedback from Semi-Structured Informal Interviews

As mentioned earlier (see section 5.4.3 on page 125), semi-structured informal interviews were carried out about two to three weeks into the MSc projects in three randomly selected monitoring groups. All interviews took place at the end of the weekly monitoring meeting and were aimed at collecting general feedback concerning the monitoring scheme and meetings, on the monitoring system features and their perceived usefulness, suggestions for improving the system or additional features desired, and answering questions students had regarding features and their use.

Student feedback received in the interviews is very much in line with general comments submitted in the closing questionnaire. The most common problem encountered was that students did not know about the purpose of certain features and how to use them as part of their project monitoring and/or supervision. This was despite of the system being presented to students at the beginning of their project. This clearly indicates that some features were not self-explanatory enough. Some students also attended several group meetings, especially in groups where two or more meetings were offered per week, and could not find this reflected on the system. Also, there were a few students who complained about monitors/supervisors not remembering what their project was about. Although the system provided means of indicating project title and description on the project page, many students were not aware of this feature and rarely used it.

There were also comments on particular system features. For example, one student suggested to include more detailed context information in system email reminders. Others requested more comparative charts and graphs with drill-down functionality, and they would also like the graphs to be bigger and more readable. In terms of the number of emails, students were divided: while some complained about it being to high, others explicitly requested it to be increased. The latter group of students also admitted that for them email notifications were the main incentive to use the system and that they used direct links in these emails to access the system.

6.1.5 Subjective Monitor Feedback

The closing questionnaire presented to monitors at the end of the summer projects was an adapted version of the student closing survey. It consisted of three parts: part one enabled monitors to rate the helpfulness of certain system features for MSc project monitoring, part two provided a set of general statements and asked users to rate their agreement with these statements, and part three was equivalent to the last part of the student questionnaire, asking for other online or offline tools used for project monitoring, and for general suggestions or feedback. In total, 14 out of 19 monitors (= 73.7%) submitted valid data on this questionnaire. Item scales for the first two parts are reliable with Cronbach's $\alpha = 0.872$ and 0.856, respectively. Split-half reliability analysis yields the same result with $r = 0.793$ ($N_1 = 5$, $N_2 = 4$) for helpfulness ratings, and $r = 0.915$ ($N_1 = 3$, $N_2 = 2$) for agreement ratings.

6.1.5.1 Feature Helpfulness for Project Monitoring

In this part of the questionnaire, monitors were asked for their perceived helpfulness of system features on a scale from 0 to 5 with 0 denoting "did not use", 1 being "not helpful at all", and 5 indicating "extremely helpful". All 14 respondents provided valid answers to all 9 items; the results are shown in Table 6.8.

Table 6.8: Perceived feature helpfulness for project monitoring

			Percentage %					
#	Feature	Mean	0	1	2	3	4	5
1	Dashboard and charts	2.00	28.6	7.1	<u>28.6</u>	14.3	14.3	7.1
2	Student ranking	2.29	28.6	7.1	14.3	14.3	<u>28.6</u>	7.1
3	News feed	2.86	7.1	21.4	14.3	14.3	<u>21.4</u>	<u>21.4</u>
4	Email notifications	3.57	0.0	21.4	0.0	7.1	<u>42.9</u>	28.6
5	Progress feedback	3.86	7.1	0.0	0.0	28.6	21.4	<u>42.9</u>
6	Event attendance feedback	3.71	7.1	0.0	14.3	14.3	21.4	<u>42.9</u>
7	Event/meeting organisation	3.71	7.1	0.0	7.1	21.4	<u>35.7</u>	28.6
8	Comments on group pages	3.07	7.1	14.3	14.3	14.3	<u>28.6</u>	21.4
9	Data export	2.29	21.4	14.3	14.3	<u>28.6</u>	7.1	14.3

Features perceived most helpful for project monitoring were the news feed (42.8% of respondents found this feature helpful or extremely helpful), weekly progress feedback as well as event attendance feedback (42.9%), email notifications (42.9%), and meeting organisation (35.7%). In contrast, the dashboard and charts were perceived less helpful with 35.7% of respondents rating them not helpful (2) or not helpful at all (1). However, together with the student ranking table and the data export it was also one of the least used features of the system with 28.6% of respondents indicating that they did not make use of it in their monitoring process.

6.1.5.2 Agreement with General Statements

The questionnaire also provided five general statements and asked monitors to rate their agreement with them on a Likert scale from 1 to 5, whereby 1 stands for "don't agree at all", and 5 for "fully agree". The statements were rated by all 14 respondents and there were no missing values.

The results in Table 6.9 reveal that the majority of respondents think that the system helped them track student progress and enhanced overall MSc project monitoring.

Table 6.9: Agreement with general statements

			Percentage %				
#	Statement	Mean	1	2	3	4	5
1	System helped track student progress	4.00	0.0	7.1	21.4	35.7	35.7
2	System helped point out problems to students/supervisors	3.29	7.1	14.3	42.9	14.3	21.4
3	System helped monitor progress during absence	3.36	7.1	21.4	28.6	14.3	28.6
4	System helped detect problems in projects	3.21	0.0	21.4	50.0	14.3	14.3
5	System enhanced MSc project monitoring	4.00	0.0	14.3	14.3	28.6	42.9

However, users were divided over statement number 2, that is, 42.9% neither agree nor disagree, 35.7% agree or fully agree, and 21.4% disagree. The same is true for statement 4.

6.1.5.3 General Feedback

The last part of the survey looked at other tools monitors used for project monitoring, and at any comments respondents provided regarding the system and how it could be improved.

Regarding tool usage, 5 users (35.7%) indicated they also used email software. Other tools mentioned were instant messaging software (2 users), online social networks (1 user), and a log book (1 user).

A total of 8 users (57.1%) submitted textual feedback on the system, its usefulness, and possible improvements. Most of their comments were very detailed and the key points can be summarised as follows:

- The system was useful for tracking student attendance, especially in cases where students did not attend meetings for more than one week in a row, and also for giving students feedback on their work relative to the rest of the group. It is believed that this may have motivated students to do better projects.
- The meeting calendar enabled monitors to communicate meeting dates and times easily to all students in the group.
- It is suggested to add more communication features so that direct interaction with students is possible. This became particularly apparent at the end of the project, when some students asked their monitor to give them feedback on their writing. While monitors used the system to provide qualitative and quantitative feedback on their writing, they still had to use other tools (for example email) to give detailed feedback on particular sections of the report. Direct email, instant messaging, and file upload integration are proposed as possible solutions.

- The user interface was found to be too complicated and not user-friendly enough, and insufficient help and how-to guidelines were provided.
- Too many email notifications were sent to monitors and supervisors which might have disrupted their normal workflow or spammed their inboxes.
- The news feed was perceived useful but contained too many messages of minor importance so that more important ones were sometimes overlooked.
- Some monitors found the system was mostly used unidirectional, that is, information flow was from monitor to student.

In summary, most of this feedback goes in line with that of students, especially with regard to user interface, email notifications, and communication features. However, most monitors also provided concrete suggestions for mitigating or solving existing problems in order to make the system more useful in the future.

6.2 Results

In this section, the data collected during the experiment is analysed in order to establish whether main hypotheses 5.1 to 5.3 in section 5.3 on page 119 hold. This is achieved by using the statistical tests described in section 5.6.3, first and foremost correlation analysis methods since a quasi-experimental study is conducted.

6.2.1 Analysis of Hypothesis 1

It was claimed earlier that there is a positive and significant relationship between the use of features associated with technology-supported learning aspects (TSLAs) and student motivation, progress, and performance (see Hypothesis 5.1 on page 121). Before this hypothesis can be examined, the metric "feature use" and its meaning need to be defined in more detail.

Definition 6.1. Feature use $a\left(u, c_i, t_0, t_1\right)$ is defined as the total number of interactions of a user u with a feature c_i of the system at time interval $[t_0, t_1]$. Note that the terms "features use" and "feature activity count" are used synonymously in the remainder of this work. The list of 30 possible features c_i ($i = 1 \ldots 30$) is shown in Table 6.10. Setting $t_0 = \min(T)$ and $t_1 = \max(T)$, where T is the set of all times in the interaction log, $a\left(u, c_i, t_0, t_1\right)$ yields the total number of interactions with feature c_i for user u over all 17 project weeks.

Definition 6.2. Total system use $s(u)$ is defined as the total number of interactions of a user u with any feature c_i of the system at time interval $[t_0, t_1]$, such that

$$s(u) = \sum_{i=1}^{30} a\left(u, c_i, t_0, t_1\right)$$

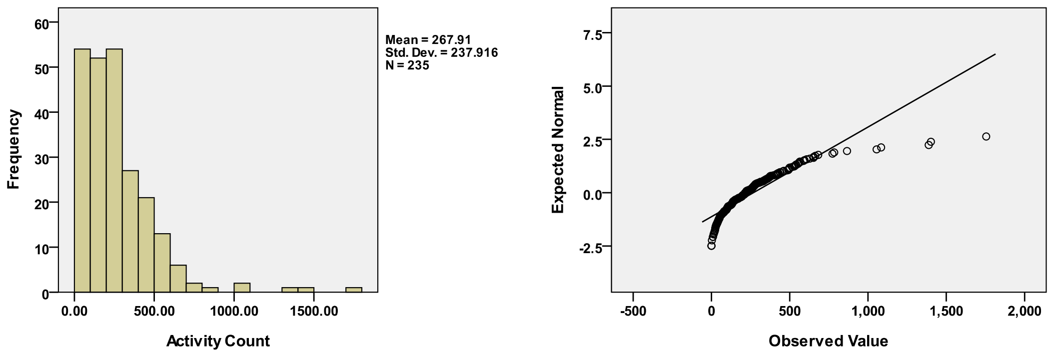
The terms "system use" and "system activity count" are used synonymously. Similar to Definition 6.1, setting $t_0 = \min(T)$ and $t_1 = \max(T)$, where T is the set of all times in the interaction log, $s(u)$ yields the total number of interactions with all 30 system features for user u over all 17 project weeks.

Table 6.10: System features c_i

Feature Category	**Feature Name**	i
Event/appointment	Delete	1
	View Details	2
	Insert	3
	Update	4
Data export	Insert	5
	Delete	6
	View	7
Group page	View	8
	Update Details (e.g. title, description)	9
Help about a feature	Show	10
Home page (feedback, dashboard, ranking)	View	11
News feed	Go to event	12
	Go to group page	13
	Go to project page	14
	Go to task	15
Group notes page	View	16
Project page	View	17
	Update details (e.g. title, description)	18
Statistics dashboard (on home page)	View	19
Task (on project page)	Delete	20
	View details	21
	Insert	22
	Update	23
User	Login	24
	Logout	25
	View profile of other user	26
	Upload profile picture	27
	Remove uploaded profile picture	28
Progress feedback	Submit	29
Event feedback	Submit	30

For some of the features in Table 6.10, there may be some overlap of system use numbers. For example, the statistics dashboard with charts was displayed on the home page, so that every home page hit also counts as a dashboard hit. In contrast, since the user could switch between several charts on the dashboard without reloading the whole page, not every dashboard hit also counts as a home page hit. Furthermore, some features such as the ranking table did not provide means for user interaction and are therefore not contained in the list of features. Academic performance was measured using the final dissertation mark, which is solely based on the project work.

The hypothesis was then examined using the Spearman correlation test because feature use is non-normally distributed and hence non-parametric. This was verified using the Kolmogorov-Smirnov test ($D(272) = 0.160$, $p < 0.01$), showing that the distribution of total system use is significantly different from the normal distribution. This also becomes apparent from the Q-Q plot shown in Figure 6.2.1b where the plot of observed values (system use count) does not follow the line representing the expected normal distribution.



(a) Histogram of system use (b) Q-Q plot of system use

Figure 6.2.1: System use plots

6.2.1.1 Feature Use

In order to test for relationships with feature usage, the following input variables were used in the analysis. For simplicity reasons, feature activity counts were combined by category. For example, event feature use corresponds to the sum of activity count values for features 1 to 4 in Table 6.10, and so on. More specifically, input variables are:

Event: The sum of activity count values for features 1 to 4, such that $a_{\text{Event}} = \sum_{i=1}^{4} a\left(u, c_i, \min(T), \max(T)\right)$

Data Export: The sum of activity count values for features 5 to 7, such that $a_{\text{Export}} = \sum_{i=5}^{7} a\left(u, c_i, \min(T), \max(T)\right)$

Group The sum of activity count values for features 8 and 9, such that $a_{\text{Group}} = \sum_{i=8}^{9} a\left(u, c_i, \min(T), \max(T)\right)$

Home The activity count value for feature 11, such that $a_{\text{Home}} = a\left(u, c_{11}, \min(T), \max(T)\right)$

News Feed The sum of activity count values for features 12 to 15, such that $a_{\text{News}} = \sum_{i=12}^{15} a\left(u, c_i, \min(T), \max(T)\right)$

Group Notes The activity count value for feature 16, such that $a_{\text{Notes}} = a\left(u, c_{16}, \min(T), \max(T)\right)$

Project The sum of activity count values for features 17 and 18, such that $a_{\text{Project}} = \sum_{i=17}^{18} a\left(u, c_i, \min(T), \max(T)\right)$

Charts The activity count value for feature 19, such that $a_{\text{Charts}} = a\left(u, c_{19}, \min(T), \max(T)\right)$

Tasks The sum of activity count values for features 20 to 23, such that $a_{\text{Tasks}} = \sum_{i=20}^{23} a\left(u, c_i, \min(T), \max(T)\right)$

Profile The activity count value for feature 26, such that $a_{\text{Profile}} = a\left(u, c_{26}, \min(T), \max(T)\right)$

Progress Feedback The activity count value for feature 29, such that $a_{\text{Profile}} = a\left(u, c_{29}, \min(T), \max(T)\right)$

Event Feedback The activity count value for feature 30, such that $a_{\text{Profile}} = a\left(u, c_{30}, \min(T), \max(T)\right)$

Emails The number of automatic email notifications sent by the system

Mark The dissertation mark, which is the result of summative assessment conducted on the MSc dissertation in September/October 2010

Progress Three variables denoting the overall student progress ratings submitted by students themselves (p_1), their monitor (p_2), and their supervisor (p_3)

Motivation Three variables denoting the student motivation ratings submitted by students themselves (m_1), their monitor (m_2), and their supervisor (m_3)

The Spearman correlation test yields the results shown in Table 6.11, whereby for each feature the corresponding TSLA is also given. They are abbreviated as follows: "TM" stands for time management, "M" for motivation, "PA" for progress awareness, and "MN" for monitoring. Only significant correlations are shown and insignificant relationships are denoted by an empty cell.

None of the features in Table 6.11 correlates with the taught mark. However, the table shows some interesting patterns:

Table 6.11: Feature use variables and correlations with performance, progress and motivation

Feature	TSLA(s)	Diss. Mark	p_1	p_2	p_3	m_1	m_2	m_3
Event	TM		.144*	.167*				
Data Export	–				.199*	.186*		.221*
Group	TM			.221**	.212*		.197**	.224*
Home	M	.201**	.230**	.212**	.248**	.213**	.225**	.263**
News Feed	PA			.195**	.207*		.163*	.192*
Group Notes	MN							
Project	TM	.210**	.215**	.152*	.250**	.199**	.145*	.225*
Charts	M, PA	.196*	.211**	.212**	.246**	.189**	.211**	.253**
Tasks	TM	.144*			.204*			.184*
Profile	M, PA	.166**	.182**	.140*	.261**	.198**		.237*
Progress Feedback	M, MN	.154*	.231**	.286**	.252**	.178**	.305**	.252**
Event Feedback	M, MN		.168*	.195**	.238*		.171*	
Emails	M, PA							

1. Event usage seems to have positively affected overall progress ratings submitted by students and monitors, but not those of supervisors.

2. Use of the virtual group page and interactions with the news feed positively affected overall progress ratings submitted by monitors and supervisors, but not those of students.

3. Use of the virtual project page and interactions with charts positively affected student performance, overall progress and motivation.

4. There is a positive relationship between interactions with project tasks and student performance and supervisor-rated student progress as well as motivation.

5. Submissions of progress feedback seem to have positively affected student performance, overall progress, and motivation, while submissions of event attendance feedback positively affected student motivation and monitor-rated overall progress.

6. Views of other user profiles positively affected student performance, motivation, and self-rated as well as supervisor-rated student progress.

Drilling down into interactions with different types of charts/graphs, the correlations listed in Table 6.12 were obtained. At this point, the reader is reminded of the charts provided in the system: (i) four histograms showing the distribution of progress, motivation, and report quality ratings for the current calendar week, including a marker showing the current user's rating in each histogram, (ii) as before, but showing ratings for the previous calendar week, (iii) a graph showing four lines plotting ratings over the last 10 calendar weeks, (iv) a graph showing the current student's event attendance over the last 10 calendar weeks, (v) a graph showing quantitative report metrics (word count/pages) over the last 10 calendar weeks, (vi) a bar chart showing the current student's progress on each of the four project milestones, and (vii) a bar chart showing absolute numbers of total, incomplete, complete, and overdue tasks in the current student's task list.

Table 6.12: Chart use correlations with performance, progress and motivation

Feature	TSLA(s)	Diss. Mark	p_1	p_2	p_3	m_1	m_2	m_3
Histograms Current Week	M, PA	.188**	.180**	.203**	.217*	.168*	.204**	.217*
Histograms Last Week		.181**	.204**	.207**	.286**	.156*	.210**	.311**
Performance Trend		.241**	.157*	.203**	.252**	.177**	.191**	.316**
Attendance Trend		.202**	.168*	.142*		.192**	.139*	.200*
Report Metrics Trend		.162*			.193*	.136*		.214*
Task Milestones				.143*	.205*		.150*	.196*
Task Statistics								

The results suggest that student usage of the first three charts had positive effects on student performance, progress, and motivation throughout, while the attendance trend graph does not seem to have affected supervisor-rated student progress. Furthermore, there is a positive relationship between usage of the report metrics trend graph and student performance, student and supervisor-rated progress, and supervisor-rated student motivation. Overall student progress rated by monitors and supervisors also correlates with student use of the task milestone bar chart, while the task statistics chart does not correlate with any of the given variables.

6.2.1.2 On the Relationship Between Ratings and Student Performance

When assessing existing correlations between usage metrics and student performance, progress, and motivation ratings, the relationship between these ratings and performance indicators (marks) is of particular interest. The aim is to establish if ratings accurately predict performance and if ratings are inter-correlated, that is, if there are discrepancies between ratings submitted by different user roles. Table 6.13 shows existing correlations between ratings and student performance.

Table 6.13: Correlations between ratings and student performance

Variable	Taught Mark	Diss. Mark	p_1	p_2	p_3	m_1	m_2	m_3
Taught Mark	1.0	.646**	.224**	.219**	.348**	.213**	.186**	.371**
Diss. Mark	.646**	1.0	.357**	.167*	.455**	.338**	.143*	.503**
p_1	.224**	.357**	1.0		.392**	.814**	.149*	.344**
p_2	.219**	.167*		1.0	.506**		.945**	.438**
p_3	.348**	.455**	.392**	.506**	1.0	.353**	.438**	.873**
m_1	.213**	.338**	.814**		.353**	1.0		.314**
m_2	.186**	.143*	.149*	.945**	.438**		1.0	.501**
m_3	.371**	.503**	.344**	.438**	.873**	.314**	.501**	1.0

The results show that ratings from all users correlate positively with both taught and dissertation mark. This suggests that students who performed well on their taught part received higher progress and motivation ratings in the course of the summer project and also achieved higher marks on their dissertation. For most user roles, effect sizes of correlations are slightly higher regarding the dissertation mark (p_1, p_3, m_1, and m_3), except on those ratings submitted by monitors (p_2 and m_2). What is more, ratings also correlate positively with each other in most cases. In particular, progress ratings correlate positively and very strongly with motivation ratings for all user roles ($0.873 \leq r_s \leq 0.945$, $p < 0.01$). This means that students who made better progress on their project also received higher motivation ratings and vice versa. Another interesting finding is that both progress and motivation ratings do not correlate significantly between student and monitor user roles.

6.2.2 Analysis of Hypothesis 2

Hypothesis 5.2 is about measurable changes in student behaviour and perception as a result of TSLA feature use, demonstrating the importance of these features for project-based self-regulated learning and their contribution to four of Chickering and Gamson's [1987] seven principles, namely (i) enhance student faculty contact, (ii) emphasising time on task, (iii) providing prompt feedback, and (iv) communication of high expectations. This hypothesis also comes with four sub-claims (see Table 6.14), in which system features are aligned with a corresponding principle they support.

In order to analyse this hypothesis, results for the first hypothesis presented in the previous section need to be revisited and combined with subjective feedback provided by students in the closing questionnaire. More specifically, usage data, correlations with performance and weekly ratings, the perceived helpfulness of features for project management, and the perceived motivational effect of features are analysed. Furthermore, the criteria for successfully supporting a principle need to be established:

Table 6.14: System features supporting four out of Chickering and Gamson's seven principles

Features	Supported Principle(s)
Progress Feedback Event Feedback Visualisations Group Page Email Notifications Group Comments	Encouraging student-faculty contact
Project Page Task List Event Calendar Group Page	Putting time on task first
Visualisations Ranking Table News Feed Email Notifications	Prompt feedback Communicating high expectations
Progress Feedback Event Feedback	

1. The first principle is about encouraging student-faculty contact. According to Chickering and Gamson [1987], frequent contact between members of the faculty and students is a key facilitator of student motivation and involvement. It can also help in overcoming difficulties and enhancing student persistence when performing learning tasks. Consequently, the question to ask in the context of this research study is whether features enabling motivation and communication led to increased student motivation and involvement. Motivation was rated by the student themselves, their monitor, and their supervisor on a weekly basis. Furthermore, students rated the perceived motivational effect of features in the closing questionnaire.

2. Emphasising time on task is another important principle, which is supposed to make students learn to use their time well [Chickering and Gamson, 1987]. Hence, the data needs to be analysed regarding the perceived helpfulness of time management features for project management and weekly rated overall progress of students in the course of the summer project.

3. The provision of prompt and appropriate feedback is considered a central aspect of learning [Chickering and Gamson, 1987]. It enables students to reflect on their achievements, learn how to assess their own learning, and react appropriately. This is very much in line with the process of self-regulated learning [Zimmerman, 2011]. The question in this context is whether student behaviour changed in response to feedback and how.

4. Finally, Chickering and Gamson [1987] also recommend the communication of high expectations to students. The aim is to expect high performance from students in

order to motivate poorly prepared, unwilling, and well-motivated students equally. The data must be analysed regarding possible effects of weekly ratings from monitors and supervisors on student behaviour, mainly their own motivation ratings and their academic performance at the end of the project.

For the analysis of feature support of these four principles, correlation tests were used on the data collected in system logs and the closing questionnaire.

6.2.2.1 Encouraging Student-Faculty Contact

The monitoring system was designed for enabling information exchange between students, monitors, and supervisors, although the primary emphasis was on students and monitors – supervisors were not required to use the system and in fact only used it sporadically (see section 6.1.1 on page 151). A great deal of contact time was devoted to weekly monitoring and supervision meetings, while the web-based monitoring system was meant to complement the scheme and help to make it more effective.

Before the analysis, two types of student-faculty contact need to be distinguished. *Active contact* denotes that there is frequent interpersonal interaction between a member of the faculty and the student, either face-to-face or electronically. In contrast, *passive contact* is when information is passed unidirectionally without direct interaction but with the intention to enable connectedness and awareness of ongoing communications or processes behind the scenes. For example, monitoring meetings were designed to enable active contact between monitors (faculty) and students (and among students, but this is not the primary focus of this work), while the monitoring system was designed to enable active as well as passive contact by providing means for (i) in-group electronic communications (group comments), (ii) submitting progress reports, (iii) giving event attendance feedback, and (iv) providing textual feedback on student progress. Online information submission using the last three features is always preceded by active contact between monitors and students in monitoring meetings.

Active Contact In the closing questionnaire (see section 6.1.4.4 on page 159), the majority of student respondents (38.5%) fully agreed (rating 5 out of $[1, 5]$) that monitoring meetings were helpful. Furthermore, the majority (29.8%) also agreed that their monitor or supervisor picked them up on progress reports submitted on the system. In contrast, most respondents did not find that the system helped them to communicate problems to monitors/supervisors or to contact other students. They were undecided (rating 3 out of $[1, 5]$) regarding the system's helpfulness for keeping in contact with their monitor/supervisor during their absence. From the monitor's point of view (see section 6.1.5.2), most monitor respondents were undecided (rating 3 out of $[1, 5]$) regarding the system's helpfulness in detecting (50%) and pointing out problems to students and supervisors (42.9%). However, the majority (71.4%) of respondents agreed or fully agreed that the system helped tracking student progress. In their general feedback, some monitors indicated that they found that the system was mostly used unidirectional (from monitor to student), and that more communication features should be provided to enable direct interactions.

Use of the group comment feature does not correlate with any student motivation ratings. This finding can be explained by supervisors not contributing much to electronic discussions in monitoring groups, therefore it is unlikely that student use of this feature affected their weekly feedback. Furthermore, only very few users (46 in total) used this feature (see section 6.1.1), with monitors being the most active, creating 1 note while students only created 0.21 notes on average. The number of interactions with the feature is also small with only 68 interactions in total over a 17-week period, compared to views of the home page, for example, which got well over 10,000 hits in the same period from 343 users. The absence of a significant effect on student motivation is therefore not surprising. In the closing questionnaire, however, the majority of student respondents (33.7%) found that the group comments feature motivated or motivated very much (4 and 5 out of $[1, 5]$).

Passive Contact The primary aim of student-faculty contact is to motivate students [Chickering and Gamson, 1987]. In the monitoring system, the motivation aspect is represented by five features, namely (i) progress feedback, (ii) event feedback, (iii) visualisations, (iv) the ranking table, and (v) email notifications. In the previous section (6.2.1), correlations between feature usage data and student performance, progress, and motivation were analysed. This section will focus on the effects of using the five main motivation features on weekly motivation ratings submitted through the system. Table 6.11 on page 168 lists all correlations found for any of the features. Submissions of progress feedback correlate positively and significantly ($p < 0.01$) with student motivation ratings from all three user roles, while event feedback only had a positive effect on monitor-rated student motivation. The visualisations (charts) correlate positively and significantly ($p < 0.01$) with self-rated ($r_s = 0.188$), monitor-rated ($r_s = 0.211$), and supervisor-rated ($r_s = 0.251$) average weekly student motivation ratings, in other words, students who viewed these visualisations often also indicated higher motivation and received higher motivation ratings from both their monitor and supervisor. In particular, significant ($p < 0.05$) and positive correlations exist for the use of histograms showing the current and past calendar week's performance metrics, the performance trend graph, and the attendance trend graph. The former two charts enabled students to compare themselves with other students studying on the same programme or those in their monitoring group. Furthermore, views of the group page correlate positively with monitor and supervisor-rated student motivation ($p < 0.05$). Finally, the number of email notifications sent to students did not have a direct effect on their motivation ratings.

In the closing questionnaire, student respondents were given the opportunity to rate the perceived motivational effect of certain system features (see section 6.1.4.1). The majority of respondents indicated that the features charts, the ranking table, progress reports, event feedback, and email notifications motivated or motivated very much (4 and 5 out of $[1, 5]$).

Correlations between subjective student feedback, usage data of features, and weekly motivation ratings were also analysed. Closing questionnaire responses correlate highly and significantly with each other; this was already shown in section 6.1.4 on page 156 as part of the questionnaire reliability analysis. Generally, student feature use does not correlate with student agreement with general statements with one exception: use of group comments correlates positively and significantly with agreement with statement "the system helped communicate problems" ($r_s = 0.235$, $p < 0.05$). Regarding the perceived motivational effect of features, submissions of progress reports correlate positively and significantly with the perceived motivational effect of monitor progress feedback and event attendance feedback ($r_s = 0.208$ and $r_s = 0.215$ with $p < 0.05$, respectively). Similarly, the use of attendance feedback correlates with the motivational effect of that feature ($r_s = 0.198$, $p < 0.05$). Student use of charts correlates positively ($p < 0.05$) with the perceived motivational effect of the ranking table ($r_s = 0.226$), monitor-reported progress ($r_s = 0.232$), and supervisor-reported progress ($r_s = 0.221$). There is also a positive correlation between the use of group comments and perceived motivational effect of self-reported progress ($r_s = 0.201$, $p < 0.05$) and event attendance feedback ($r_s = 0.289$, $p < 0.01$). Finally, correlations of subjective student feedback with the dissertation mark and weekly ratings are as follows: (i) agreement with statement "the system helped communicate problems" correlates with self-rated student progress ($r_s = 0.215$, $p < 0.05$) and (ii) the degree of monitoring meeting helpfulness correlates with monitor-rated student progress and motivation ($r_s = 0.267$ and $r_s = 0.257$ with $p < 0.05$, respectively).

In summary, features enabling active contact (direct interactions or dialogues) were considered motivational but usage statistics suggest that they were not used frequently by a majority of students. Furthermore, they were only provided in the context of monitoring groups and not in student projects, narrowing down the number of potential participants and ways of interaction. It can be assumed that most direct communication took place by other means such as email or face-to-face conversation. Data about such interactions or conversations in monitoring meetings was not recorded and hence not used in this analysis. Group comments were mainly used by monitors to make announcements to the group, and usage of this feature does not correlate with student motivation ratings. Conversely, features enabling passive contact (visualisations, ranking table, group and project page) correlate positively and significantly with student motivation ratings and were perceived motivational by a majority of student respondents in the closing questionnaire. These features can be assumed to reflect the impression monitors and supervisors got from students during weekly meetings. Furthermore, use of visualisations positively affected the perceived motivational effect of the ranking table and monitor as well as supervisor-reported student progress. Students who indicated that they found monitoring meetings helpful also received higher progress and motivation ratings from their monitor. Likewise, those who found that the system helped them communicate problems to their monitor/supervisor submitted higher weekly project progress ratings.

6.2.2.2 Emphasising Time on Task

Time management is considered one of the key skills facilitating effective learning. Chickering and Gamson [1987] synthesise this by saying "time plus energy equals learning" and that "there is no substitute for time on task". Likewise, strategic planning and time management are key aspects of self-regulated learning [Zimmerman, 2011]. The web-based monitoring system provides a set of features supporting these aspects: (i) a project page giving an overview of the project title, description, people associated with it (student, monitor, supervisor), (ii) a list of project tasks with urgency flags and a set of predefined milestone tasks, and (iii) an event calendar showing project and group-related events. Similarly, the virtual group page provides a group calendar and space for group comments, which were predominantly used by monitors to make announcements to group members (see previous section for details).

In the closing questionnaire, the majority of student respondents considered the task list (49.6%) and the event calendar (49%) helpful or very helpful for project management (see section 6.1.4.2 on page 158). Most system users also used these features actively during the 17-week period with 266 and 202 users, respectively. However, only 3.1% and 1.8% of all system interactions occurred on the task list and events, respectively, making them some of the least-used system features (see section 6.1.1 on page 151). The number of tasks managed using the online system was also small: students had an average of 4.3 tasks in their list, 4 of which were milestone tasks which were there by default. A minority of supervisors also used their students' task list to add tasks to their projects, while monitors did not create any tasks in their students' projects. Events were mainly created by monitors (7.37 events on average) and supervisors (1.32 events on average), while students made less use of this feature (0.91 events on average). It was also analysed whether students might have used external tools for managing their project tasks. The data export feature was used by 248 users, but only 1.04% of interactions were made with it, that is, it was not used frequently. However, 17.4% of questionnaire respondents indicated that they used other tools such as Microsoft project and paper-based log books for managing their project (see section 6.1.4.5 on page 160).

Positive and significant correlations exist between the use of tasks and students' dissertation mark, supervisor-rated progress ratings, and supervisor-rated motivation ratings (see section 6.2.1). In other words, students who used tasks more frequently also achieved a higher mark on their dissertation and higher progress and motivation ratings from their supervisor. However, usage of this feature does not seem to affect students' own perceived progress and motivation. In contrast, event use correlates positively and significantly with self and monitor-rated project progress, but not with any motivation or supervisor ratings. Significant and positive relationships also exist between views of the project page and performance, progress, and motivation ratings of students. Conversely, group page views only correlate with monitor and supervisor-rated student progress and motivation.

The analysis of correlations between feature use, subjective student feedback, and performance as well as weekly progress ratings yields the following results: (i) no significant correlations were found between feature use and agreement with general statements in the closing questionnaire, (ii) closing questionnaire responses correlate significantly with each other, (iii) students' perceived helpfulness of event/meeting management features correlates with self-rated weekly progress ($r_s = 0.204$, $p < 0.05$).

In summary, tasks and events were rated helpful for project management by the majority of student respondents to the closing questionnaire and correlate positively and significantly with student progress ratings submitted by some user roles. This also applies to the virtual project page. Furthermore, students who found the event calendar helpful for project management reported higher weekly project progress. However, tasks and events were used infrequently compared to other system features and positive correlations should be seen in light of these statistics.

6.2.2.3 Provision of Prompt Feedback

In the monitoring system, feedback can be submitted on a weekly basis by students, monitors, and supervisors. It consists of the student's (i) overall project progress, (ii) motivation, (iii) report quality, (iv) quantitative report metrics (pages/words), (v) event attendance (in monitoring/supervision meetings). Furthermore, textual feedback can be provided once a week together with these ratings. Weekly feedback was preceded by meetings, that is, monitors, students, and supervisors normally provided it in response to face-to-face interaction. Some monitors also reported that students who could not be present in meetings sent them status updates via email, in which case weekly feedback was provided based on these emails. Features supporting the submission of feedback were online progress and event feedback forms, while features visualising feedback were (i) charts and graphs, (ii) the ranking table, and (iii) the news feed. Email notifications were used for both purposes: they were sent to users in order to remind them to submit weekly feedback and in response to feedback submitted on the system (news feed emails).

Closing questionnaire responses (see section 6.1.4.2 on page 158) suggest that the majority of student respondents found both monitor-rated and supervisor-rated progress feedback very helpful for managing their MSc project (29.2% and 37.1%, respectively), though supervisor-rated feedback was perceived more helpful than that of monitors. Similarly, event attendance feedback, the ranking table, the news feed, and email notifications were perceived helpful by most respondents (31.7%, 27.6%, and 29.4%, respectively). In contrast, most students (27.1%) were undecided regarding the helpfulness and motivational effect of charts visualising progress feedback and the motivational effect of the news feed. The same applies to general statements (see section 6.1.4.4 on page 159): the majority of respondents did not find that the system helped them to communicate problems or keep in contact with their supervisor/monitor during periods of absence. However, 50% of them agreed or fully agreed that the system raised their progress awareness.

When it comes to correlations with student performance, progress, and motivation ratings, the following results were obtained (see Table 6.11 on page 168): (i) the submission of event attendance feedback correlates positively with students' weekly progress ratings and monitor-rated motivation, (ii) event reminder emails received by students correlate positively with monitor-rated student progress and task state reminder emails correlate negatively with student-rated progress as well as motivation, (iii) there is a correlation between the student use of charts and student performance as well as weekly student progress and motivation ratings, (iv) student use of the news feed correlates positively with monitor and supervisor-rated weekly student progress and motivation, and (v) views of the home page, which contained the ranking table, are positively correlated with student performance, progress, and motivation.

There also exist correlations between subjective student feedback regarding general statements in the closing questionnaire, feature use variables, and student performance, progress, as well as motivation variables:

1. The use of the news feed correlates positively ($p < 0.05$) with perceived helpfulness of monitoring meetings ($r_s = 0.201$) and agreement with "monitor/supervisor picked me up on progress reports" ($r_s = 0.206$), "the system helped to communicate problems" ($r_s = 0.234$), "the system helped to keep in contact with faculty staff" ($r_s = 0.232$), "the system helped to keep myself organised" ($r_s = 0.210$), and "the system enhanced MSc project management" ($r_s = 0.222$).

2. Student views of the home page (containing the ranking table) correlate positively with perceived helpfulness of supervisor-reported progress for project management ($r_s = 0.231$, $p < 0.05$).

3. Student use of the news feed correlates positively with perceived helpfulness for project management of features event/meeting organisation ($r_s = 0.208$), progress reports from monitors ($r_s = 0.204$, $p < 0.05$) and supervisors ($r_s = 0.211$, $p < 0.05$), the ranking table ($r_s = 0.348$, $p < 0.01$), and charts ($r_s = 0.239$, $p < 0.05$).

4. Student use of charts and graphs correlates positively with perceived helpfulness of supervisor progress feedback for project management ($r_s = 0.223$, $p < 0.05$), but there are no significant correlations with perceived helpfulness of any of the charts.

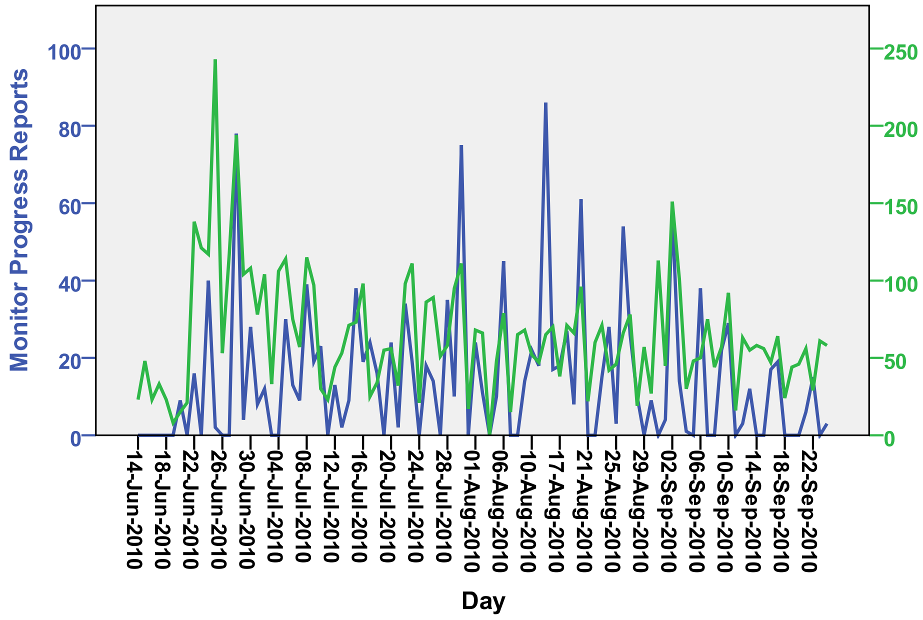
5. Students' perceived helpfulness of the news feed for project management correlates negatively and significantly at the 0.05 level with the dissertation mark ($r_s = -0.215$).

The promptness of feedback was also analysed using line graphs plotting the number of progress reports submitted on the system by monitors and supervisors against the number of student system logins for each day of the 17-week project period, depicted in Figures 6.2.2a and 6.2.2b, respectively. In both cases, student logins are in line with both monitor and supervisor progress reports. In other words, students logged on in response to monitor or supervisor feedback on the system. Students were notified of such activity by means of news feed email notifications sent automatically every 20 minutes. The student response to such emails was relatively fast, that is, in most cases students accessed the system on the same day the progress report was submitted. A Spearman correlation test was also conducted to confirm this relationship. Student logins correlate positively and significantly with monitor progress report submissions ($r_s = 0.298$, $p < 0.01$), but not with supervisor progress report submissions. Conversely, both monitor and supervisor logins correlate positively and significantly ($p < 0.05$) with student progress report submissions ($r_s = 0.442$ and $r_s = 0.128$, respectively).

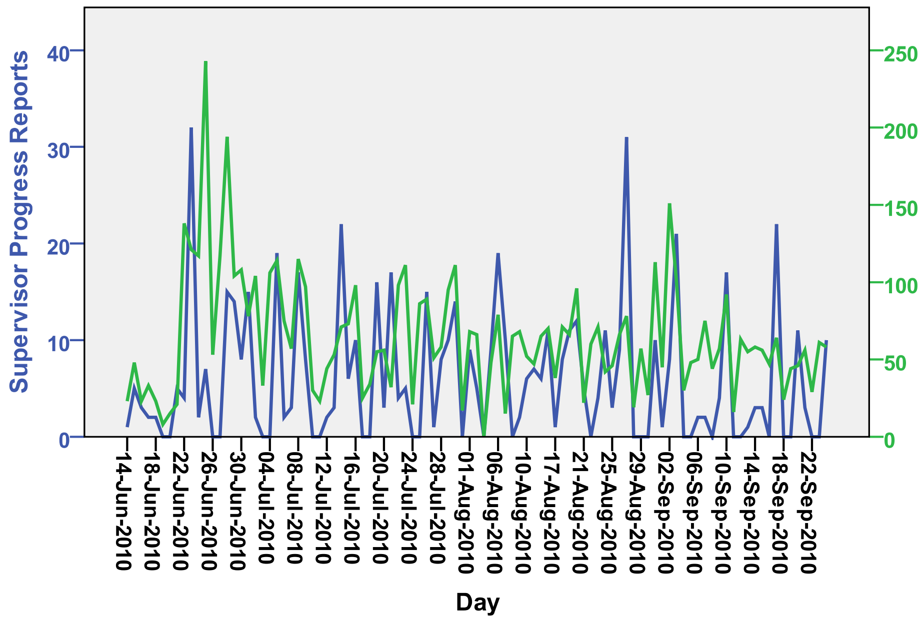
In summary, student respondents found progress reports submitted by monitors and supervisors, the ranking table, and email notifications helpful for project management. They also agreed that the system enhanced their progress awareness. However, responses on the helpfulness of charts visualising progress feedback were mixed. Correlation analysis has shown that the submission of event feedback, use of visualisations, and views of the home page positively affected students' dissertation mark as well as their weekly progress and motivation ratings. Use of the news feed also correlates positively with progress and motivation ratings submitted by monitors and supervisors. Furthermore, students making heavy use of the news feed also agreed that monitoring meetings were helpful, that faculty staff picked them up on feedback submitted on the system, and that the system helped them to communicate problems, keep in contact with faculty staff during their absence, and keep themselves organised. Those students also reported a higher perceived helpfulness of features progress reports from monitors/supervisors and ranking table, although a negative correlation with student performance was also found. Overall, Figure 6.2.2 shows that student response to feedback submitted by monitors and supervisors was relatively prompt – peaks in monitor and supervisor feedback submissions are in line with peaks in student system logins. However, correlation tests have also revealed that only the feedback submissions from monitors correlate significantly with student logins, while those of students correlate with both monitor and supervisor logins.

6.2.2.4 Communication of High Expectations

The aim of communicating high expectations is to motivate students equally regardless of their current motivational state and efficacy [Chickering and Gamson, 1987]. The analysis looked at changes in student behaviour in response to monitors' and supervisors' weekly feedback. For this purpose, the content of textual feedback provided by monitors and



(a) Monitor progress reports



(b) Supervisor progress reports

Figure 6.2.2: Plots of number of progress reports against student system logins

supervisors was analysed, while correlations with other system features for providing and visualising feedback were already presented in the previous section.

Furthermore, the data was analysed for possible effects of monitor and supervisor feedback submissions on the students' dissertation mark and motivation: supervisor progress and event attendance feedback submissions both correlate positively and significantly

($p < 0.01$) with students' dissertation mark with $r_s = 0.232$ and $r_s = 0.243$, respectively. Supervisor event attendance feedback also correlates positively and significantly at the 0.01 level with students' self-rated weekly motivation ($r_s = 0.215$), while feedback submissions from both roles do not correlate with the taught mark.

Along with their ordinal progress feedback rating (motivation and overall project progress), the system enabled all users to submit textual comments. This was to allow users to provide details in addition to their 5-point progress ratings and report metrics. The analysis of these comments revealed that they contain several types of feedback c_i ($i = 1 \dots 8$), namely

1. **Status reports** (c_1): A textual description of things the student did or did not manage to do in the course of the past week(s).

2. **Questions/answers** (c_2): Some students addressed their monitor and/or supervisor directly by asking specific questions about technical or organisational matters, and some monitors/supervisors responded and/or asked students about specific deliverables.

3. **Positive remarks** (c_3): Some examples are "XY is a very good student", "exceptional progress throughout", or "well done and keep it up".

4. **Negative remarks** (c_4), for example "XY's overall progress is slightly disappointing", "I would have expected you to...", or "the problem [...] is the length of time it is taking to express his ideas in English".

5. **Issues and problems** (c_5) preventing students from making progress on their project or tasks consuming more time than expected.

6. **Organisational remarks** (c_6), for example "XY was on leave last week" or "seen on 15 August", but also absence or problems due to illness.

7. **Success stories** (c_7), that is, the successful completion of milestones or bigger chunks of work, but also achievements outside of the project, for example, submitted conference papers or presentations given.

8. **Recommendations** (c_8) given by monitors and/or supervisors as for how work can be improved or difficulties overcome.

A combination of these 8 types of feedback was used to communicate high expectations, that is, (i) to acknowledge student achievement, (ii) to point out existing problems, and (iii) to encourage students to persist and/or move forward into a particular direction.

When analysing textual user comments, the following two-step process was applied: firstly, a list of all existing progress feedback records containing comments was compiled. This means that those records which did not contain a textual comment were not used in the analysis. Secondly, for each record, the textual comment provided by student, monitor, or supervisor was analysed as for whether it contains each of the eight types of feedback c_i ($i = 1 \ldots 8$) listed above. This was done using a binary function

$$f_i(x) = \begin{cases} 1 & \text{Comment contains } c_i \\ 0 & \text{Comment does not contain } c_i \end{cases}$$

with $i = 1 \ldots 8$ and x being the comment in the corresponding record. This analysis was performed manually on 681 existing records. The resulting $m \times n$-matrix F ($n = 8$, $m = 681$), where n denotes the number of feedback types outlined above and m the number of records, was then grouped by student, that is, all feedback concerning a student u was aggregated yielding the average of all c_i-values for each record associated with that student, such that

$$\bar{c_i}(u) = \frac{\sum_{j=1}^{m_u} f_i(x_j)}{m_u}$$

with m_u being the number of existing records for student u in F. Hence, the function $\bar{c_i}(u)$ always yields a real value between 0 and 1 for each type of feedback c_i. In addition, the number of characters $|x|$ in each textual comment was counted and also used in the following correlation test looking for relationships between $\bar{c_i}$ ($i = 1 \ldots 8$), the average length of comments $|\bar{x}|$ per students (number of characters), the taught and dissertation mark, and the average motivation and overall progress ratings submitted by students, monitors, and supervisors. The outcome is shown in Table 6.15.

The table shows that there are only correlations with feedback types c_3 to c_7, all other feedback types do not correlate with the other variables. In more detail, the submission of detailed status reports ($\bar{c_1}$) and questions/answers ($\bar{c_2}$) does not seem to affect ratings and marks, neither does the average comment length ($|\bar{x}|$) and any recommendations ($\bar{c_8}$) given by supervisors and monitors. The provision of positive remarks ($\bar{c_3}$), however, positively correlates with the student's self-rated and supervisor-rated overall progress and motivation, suggesting that supervisors gave these remarks because students were making good progress or showing good motivation, and/or students reported good progress and were more motivated as a result of these remarks. On the other hand, negative remarks ($\bar{c_4}$) do not correlate negatively with student-rated progress and motivation, but rather with those of monitors and supervisors, that is, these remarks go in line with progress and motivation ratings submitted by staff together with their feedback. Remarks concerning project issues ($\bar{c_5}$) correlate negatively with the dissertation mark, in other words, the more remarks of this kind were made the lower the final project mark; this relationship also exists with supervisor-rated overall progress and student motivation. Negative correlations were also found between remarks about organisational issues ($\bar{c_6}$) and the dissertation mark and progress/motivation ratings submitted by any user role

Table 6.15: Feedback comment metrics correlations

	Taught Mark	Diss. Mark	p_1	p_2	p_3	m_1	m_2	m_3
$\bar{c_1}$	.013	-.037	.048	.000	.073	.042	.066	.114
	.836	.554	.470	1.000	.436	.518	.340	.224
$\bar{c_2}$	-.036	-.073	-.014	-.029	-.013	-.045	-.025	-.025
	.570	.247	.829	.671	.893	.495	.718	.786
$\bar{c_3}$	-.013	.067	.181**	.125	.221*	.226**	.114	.230*
	.841	.292	.005	.069	.017	.000	.098	.013
$\bar{c_4}$	-.060	-.115	-.102	-.222**	-.410**	-.084	-.190**	-.369**
	.338	.068	.119	.001	.000	.199	.005	.000
$\bar{c_5}$	.005	-.134*	-.121	-.054	-.225*	-.062	-.038	-.225*
	.937	.034	.065	.433	.015	.345	.582	.015
$\bar{c_6}$	.001	-.125*	-.178**	-.349**	-.495**	-.154*	-.336**	-.476**
	.981	.047	.006	.000	.000	.018	.000	.000
$\bar{c_7}$	.042	.079	.156*	.037	.104	.122	.024	.122
	.504	.210	.017	.591	.268	.062	.731	.191
$\bar{c_8}$	-.090	-.051	-.008	-.012	-.106	-.028	.040	-.057
	.152	.418	.906	.862	.259	.675	.561	.543
$\bar{\lvert x \rvert}$	-.029	-.072	-.027	-.084	-.123	-.006	-.078	-.161
	.647	.252	.647	.225	.188	.923	.256	.085

(student, monitor, and supervisor). Finally, there is a positive and significant relationship between success stories ($\bar{c_7}$) and student-rated overall progress.

6.2.3 Analysis of Hypothesis 3

Hypothesis 5.3 claims that monitor behaviour affected that of students in terms of system activity as well as student performance, progress, and motivation. Consequently, the following variables were used in the analysis of this hypothesis:

- Monitor system activity, in particular the submission of progress reports (student progress and motivation) and event attendance feedback
- Student system activity: (i) system logins, (ii) access of progress data visualisations, (iii) self-reports on progress, motivation, and event attendance, and (iv) activity on the student's project page
- Student performance, that is, their dissertation mark

The analysis involved correlation tests to find relationships between variables, repeated measures tests to find time-related differences, and means comparisons to obtain between-monitor differences.

6.2.3.1 Correlations

Correlations between the above variables were obtained using a Spearman correlation test since some of the input variables are non-normally distributed. The result is shown in Table 6.16; significant correlations are marked with one or two asterisks denoting significance at the 0.05 or 0.01 level, respectively.

Table 6.16: System use inter-variable correlations (r_s)

	Student Activity							
Monitor Activity	Login	Group	Project	Tasks	Events	Charts	Progress Feedb.	Attend. Feedb.
Login	.352**	.388**	.319**	.170**	.382**	.354**	.357**	.442**
Group	.325**	.367**	.302**	.162**	.370**	.333**	.327**	.419**
Project	.324**	.319**	.262**	.165**	.291**	.294**	.328**	.382**
Events	.223**	.420**	.329**	.188**	.431**	.356**	.342**	.512**
Profile	.320**	.334**	.272**	.188**	.335**	.320**	.320**	.388**
Progress Feedback	.333**	.336**	.295**	.184**	.334**	.325**	.333**	.410**
Attend. Feedback	.298**	.387**	.283**	.185**	.418**	.309**	.310**	.523**

Feature use variables for monitors and students in this table were selected based on their relevance for this analysis. It is shown that monitor and student activity on these features correlates significantly ($p < 0.01$) throughout. The correlation coefficients indicate that monitor logins were mainly triggered by student activity on the group page, project page, the event calendar, and submission of student event attendance feedback. Similarly, student logins were mainly triggered by monitors submitting progress, their activity on the group page, and submissions of event attendance feedback; the latter also correlates strongly with student event activity and student event attendance feedback.

Similarly, correlations between the number of email notifications sent to students and their system logins were analysed. Algorithms responsible for sending these notifications were described in section 5.5.3. The number of email notifications of most types correlates positively and significantly at the 0.01 level with the number of student logins: (i) event reminder emails ($r_s = 0.467$), (ii) event attendance feedback reminder emails ($r_s = 0.363$), (iii) follow-up reminders ($r_s = 0.288$), (iv) news feed emails regarding creating ($r_s = 0.391$), changing ($r_s = 0.364$) or cancelling ($r_s = 0.308$) events, submission of event feedback ($r_s = 0.460$) and project progress feedback ($r_s = 0.462$), creation of group comments ($r_s = 0.336$) and replies ($r_s = 0.248$), and creation of project tasks ($r_s = 0.176$). Negative correlations at the 0.01 level exist between the number of student logins and progress feedback reminders ($r_s = -0.447$) and reminders about tasks becoming due ($r_s = -0.310$).

There are also interesting correlations between the number of email notifications and weekly student progress and motivation ratings, namely

- The number of event reminder emails correlates positively and significantly with monitor-rated student motivation ($r_s = 0.158$, $p < 0.05$).
- The number of follow-up reminder emails correlates negatively and significantly with monitor-rated student progress and motivation ($r_s = -0.147$ and -0.226 with $p < 0.05$, respectively), in other words, progress and motivation ratings submitted by monitors were lower for those students who received many of these emails due to their absence in a series of consecutive monitoring meetings.
- The number of progress feedback reminder emails correlates negatively and significantly with student-rated progress and motivation ($r_s = -0.302$ and -0.266 with $p < 0.01$, respectively). Those emails were only sent to students who failed to log in to submit weekly feedback on their project by the end of the week.
- The number of task state reminders also correlates negatively with student-rated progress and motivation ($r_s = -0.242$ and -0.141 with $p < 0.05$). Task state reminders were issued in response to at least one task in the student's task list becoming due or overdue.

In summary, monitor activity positively and significantly correlates with that of students. Similarly, some email notifications also triggered student system activity. In particular, emails reminding students of upcoming events/meetings, to submit feedback on their event attendance, and to attend monitoring meetings after a continuous absence in at least two consecutive weeks correlate with student system activity. Furthermore, changes made by monitors to events in groups (for example monitoring meetings), comments made on group pages, and monitor submission of progress or event attendance feedback also made students become active on the system. Email notifications also correlate with student progress and motivation ratings: students who did not attend a series of monitoring meetings – and therefore received a higher number of follow-up reminder emails – obtained lower progress and motivation ratings from their monitors. Similarly, the number of task state reminder emails, which were sent to students when one or more of their tasks required attention, correlates negatively with student-rated progress and motivation.

6.2.3.2 Time-Related Differences

Motivation and progress ratings were collected once every week, hence they are *repeated measures*. Furthermore, system use can be measured at discrete intervals as well. To examine the relationships between ratings of specific time intervals, a repeated measures analysis of variance (ANOVA) was conducted.

Definition 6.3. The system use for a week w is defined as

$$s(u, w) = \sum_{j=1}^{28} a\left(u, c_j, t_0(w), t_1(w)\right)$$

with u being the system user, and c_j the feature as found in Table 6.10. The user system use function a was introduced in Definition 6.2 on page 164 and yields the number of system interactions of user u with feature c_j at time interval $[t_0, t_1]$. Here, $t_0(b_i)$ and $t_1(b_i)$ are the lower and upper boundary of week w, respectively, so that a yields the total number of system interactions occurring in week w.

Student progress and motivation ratings of several weeks were combined to avoid problems arising from missing values for some weeks and users. More specifically, four consecutive weeks were combined to one week block b using the sum of variable values in these weeks, starting in calendar week 25 and ending in calendar week 41, resulting in 4 blocks b_i with $i = 1 \dots 4$, so that b_1 denotes weeks 25 to 28 of the year, b_2 weeks 29 to 32 of the year, and so on.

Definition 6.4. Student motivation m of a student u for week block b_i made up by weeks $w_1, w_2, \dots, w_4$ and submitted by user role $x \in [1, 3]$ where 1 refers to the student, 2 to their monitor, and 3 to their supervisor is defined as

$$m_{b_i}(u, x) = \frac{\sum_{j=1}^{4} m_x(u, w_j)}{4}$$

with $m_x(u, w_j)$ yielding the overall student motivation submitted by user role x for student u in week w_j of week block b_i; in other words, the average of those motivation ratings over all 4 weeks in the block.

Definition 6.5. Student progress p of a student u for week block b_i made up by weeks $w_1, w_2, \dots, w_4$ and submitted by user role $x \in [1, 3]$ where 1 refers to the student, 2 to their monitor, and 3 to their supervisor is defined as

$$p_{b_i}(u, x) = \frac{\sum_{j=1}^{4} p_x(u, w_j)}{4}$$

with $p_x(u, w_j)$ yielding the overall student progress submitted by user role x for student u in week w_j of week block b_i; in other words, the average of those progress ratings over all 4 weeks in the block.

Using the above definitions, a repeated measures ANOVA test was first carried out on weekly system use, using a factor "week" with 16 levels (one for each week) and a factor "user role" with 3 levels (one for each role), and a measure "use" representing user activity. Mauchly's test of sphericity is significant for this measure ($\chi^2(119) = 3665.590$, $p < 0.01$), hence the assumption of data sphericity is violated and the Greenhouse-Geisser estimate of sphericity $\epsilon = 0.311$ had to be used. The ANOVA test shows that system use differs significantly between weeks ($F(4.664, 1679.125) = 39.495$, $p < 0.01$) and user roles ($F(9.328) = 7.942$, $p < 0.01$). More specifically, mean system use of monitors was significantly higher than that of students ($\Delta\mu = 21.255$, $p < 0.01$), while student system activity was in turn significantly higher than that of supervisors ($\Delta\mu = 8.955$, $p < 0.01$). Between-week comparisons yielded the following results:

- System use in week 1 is significantly lower than in weeks 2 to 7 ($13.436 \leq \Delta\mu \leq 42.192$, $p < 0.05$) and week 9 ($\Delta\mu = 12.960$, $p < 0.05$).
- System use was maximal in week 3 compared to all other weeks ($p < 0.05$).

These results confirm descriptive statistics of system use described in section 6.1.1 on page 151. The aforementioned statistical results can be visualised in an estimated marginal means plot shown in Figure 6.2.3. Estimated marginal means or "unweighted means" – as they are also called – are used when comparing means from samples of unequal size, taking into account each mean in proportion to the sample size.

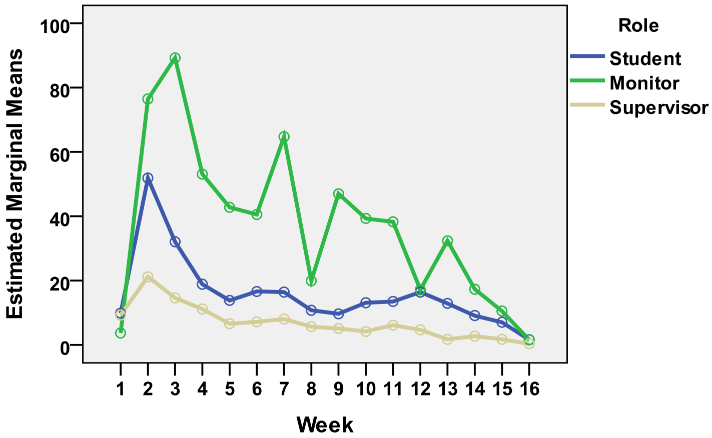


Figure 6.2.3: Estimated marginal means of system use

The analysis of student progress and motivation was conducted using two factors "week block" with 4 levels (one for each week block) and "user role" with 3 levels (one for each user role), and two measures "motivation" and "progress", representing student motivation and overall student progress, respectively. Mauchly's test of sphericity is significant for measure "motivation" in factor "user role" ($\chi^2(2) = 9.512$, $p = 0.009$), that is, the assumption of data sphericity is violated for this factor and measure. Therefore, the degrees of freedom were automatically corrected by SPSS using the Greenhouse-Geisser estimate of sphericity ($\epsilon = 0.502$).

The test results show that both student progress and motivation ratings do not differ significantly between week blocks and user roles. These results are also depicted in Figure 6.2.4, showing estimated marginal means of all measures involved.

In summary, system use differs significantly between weeks and user roles with monitors being most and supervisors being least active on the system. In total, use of the system gradually decreased in the course of 16 weeks; the last week was excluded from the analysis since system activity was very low. Although monitor activity was fluctuating compared to system use of the other two user roles, the general trend shows that student system use was very much in line with that of monitors and supervisors. Regarding weekly progress and motivation ratings, differences were insignificant between user roles

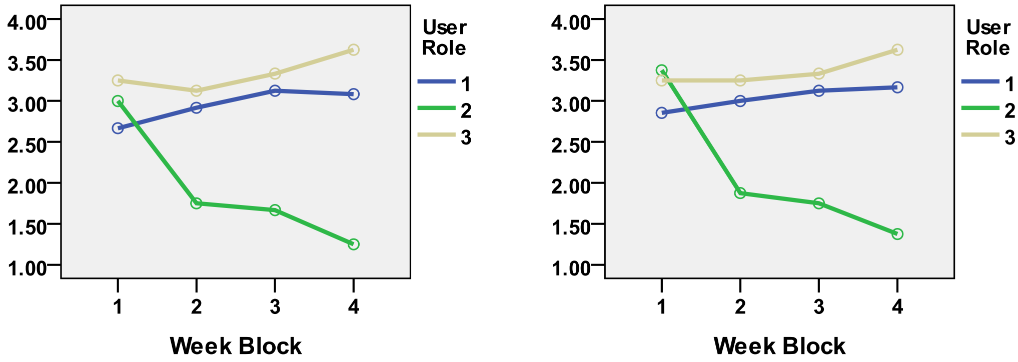


Figure 6.2.4: Estimated marginal means of measures "progress" (left) and "motivation" (middle) for user roles 1 (student), 2 (monitor), and 3 (supervisor)

and the four 4-week blocks, showing that average ratings were very similar independent of user role and throughout the 16-week period analysed.

6.2.3.3 Between-Monitor Differences

The last part of the analysis of Hypothesis 5.3 deals with potential differences between monitors in terms of their effect on student behaviour, progress, motivation, and performance. Since every student was allocated to one monitor, three questions can be asked: (i) did students of some monitors use the system more often than those of others, (ii) did students of some monitors receive higher progress and motivation ratings than those of others, and (iii) did students of some monitors get higher dissertation marks than those of others?

The student dissertation mark is normally distributed for each of the 20 monitors; this was verified using the Kolmogorov-Smirnov test by monitor. Consequently, the parametric analysis of variance (ANOVA) test can be used to compare the mean dissertation mark of students between monitors. Since sample sizes between monitors are quite different – some monitors attended to more students than others – a post-hoc procedure must be used to prevent any Type I errors from occurring. Suitable post-hoc procedures are Tamhane's T2, Dunnett's T3, Games-Howell, and Dunnett's C tests [Field, 2009]; the Games-Howell test was chosen because it is most commonly used. The one-way ANOVA test reveals that the mean dissertation mark differs significantly at the 0.01 level between monitors ($SS_M(19) = 4276.340$, $\mu^2 = 225.071$, $F = 2.582$, $p = 0.001$). Post-hoc pairwise comparisons yield that (i) students of monitors 4, 5, and 16 performed significantly better than those of monitor 7, and (ii) students of monitor 16 also performed significantly better than those of monitor 11 ($p < 0.05$). A means plot of students' dissertation mark by monitor is depicted in Figure 6.2.5.

In contrast, mean self-rated student progress and motivation ratings are non-normally distributed (Kolmogorov-Smirnov $D(223) = 0.098$ and $D(223) = 0.085$ with $p < 0.01$, respectively). Grouped by monitor, the distribution of these ratings is normal for some

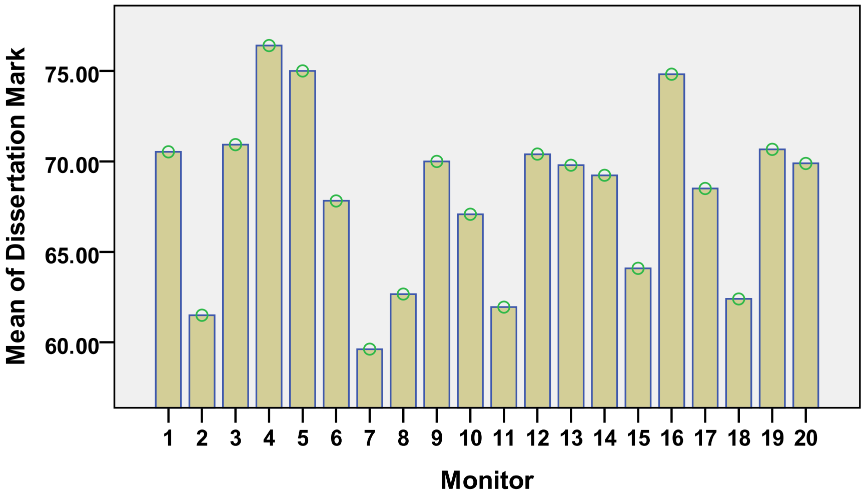


Figure 6.2.5: Dissertation mark means plot by monitors

monitors, but not for all. Therefore, the non-parametric Kruskal-Wallis test had to be used to examine between-monitor differences. The outcome reveals that there are no significant differences in self-rated student progress and motivation between monitors.

Similarly, system use is non-normally distributed overall and between monitors, so that a non-parametric test was used to analyse between-monitor differences in student system use. The Kruskal-Wallis test reveals that there are significant differences ($\chi^2(19) = 47.261$, $p < 0.01$) between monitors. Unfortunately, there are no direct post-hoc procedures for this test, so that several Mann-Whitney U tests had to be applied after carefully choosing pairs from the box plot in Figure 6.2.6, assuming that system use is significantly different between these pairs. Two comparisons were chosen: (i) monitor 3 and 5, and (ii) monitor 5 and 16, applying a Bonferroni correction so that all test result are reported at the $\frac{0.05}{2} = 0.025$ significance level. The test yields that student system use for monitor 3 was significantly higher than for monitor 5 ($U = 11.000$, $Z = -3.455$, $p = 0.001$); the same applies to monitor 16 ($U = 14.500$, $Z = -2.853$, $p = 0.004$).

In summary, significant between-monitor differences were found in student dissertation mark and student system use, but not in self-rated student progress and motivation. This indicates that some monitors seem to have affected their students' academic performance and system use, while average weekly motivation and progress remained unaffected.

6.3 Further Analysis and Interesting Results

This section presents further results not directly contributing to the main hypotheses made in section 5.3 but which give interesting insights or are indirectly relevant to this study.

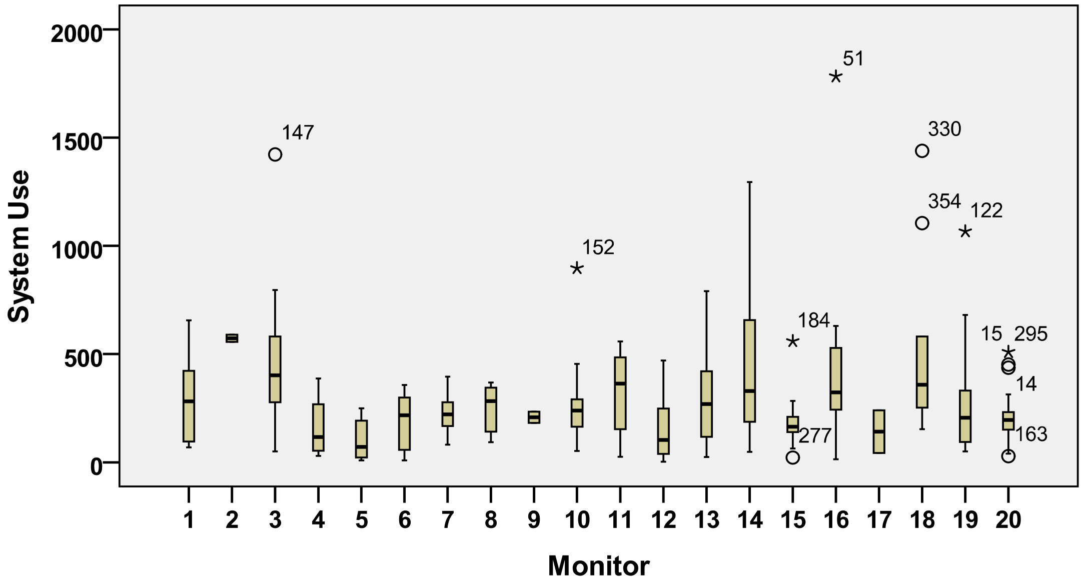


Figure 6.2.6: Box plot of student system use by monitor

6.3.1 Overall System Use

First, the relationship between total system use $s(u)$ (see Definition 6.2), the taught mark, and the dissertation mark was examined, yielding the following findings:

- A positive correlation between total system use $s(u)$ and the dissertation mark with $r_s = 0.196$ (medium effect). This correlation is significant at the 0.01 level with $p = 0.002$ and $N = 237$.
- No significant correlation between total system use and taught mark.
- A positive correlation between the taught mark and the dissertation mark with $r_s = 0.646$ (strong effect). This correlation is significant at the 0.01 level with $p < 0.01$ and $N = 239$.

In other words, system use positively influenced students' dissertation mark, while there is no significant statistical relationship between system use and the taught mark. A visual representation of this relationship is shown in Figure 6.3.1. It is noticeable that there are only a few heavy system users, while the majority used the system rather sporadically. Furthermore, there are a few cases with exceptionally high activity counts which could be considered outliers (see the box plot in Figure 6.3.2a). To ensure that the correlation is robust, the correlation test was repeated on a data set without outliers. For this purpose, the interquartile range was used to identify cases with activity count outliers, that is, those users u_i with $s(u_i) < Q_1\left(s(u_i)\right) - 1.5 \cdot IQR_{s(u_i)}$ or $s_{u_i} > Q_3\left(s(u_i)\right) + 1.5 \cdot IQR_{s(u_i)}$. For simplicity reasons, these cases were eliminated from the data set, yielding a non-normal distribution with a total number of $N = 243$ valid cases used in the correlation test excluding outliers, as opposed to $N = 252$ including outliers (see Figure 6.3.2b). The

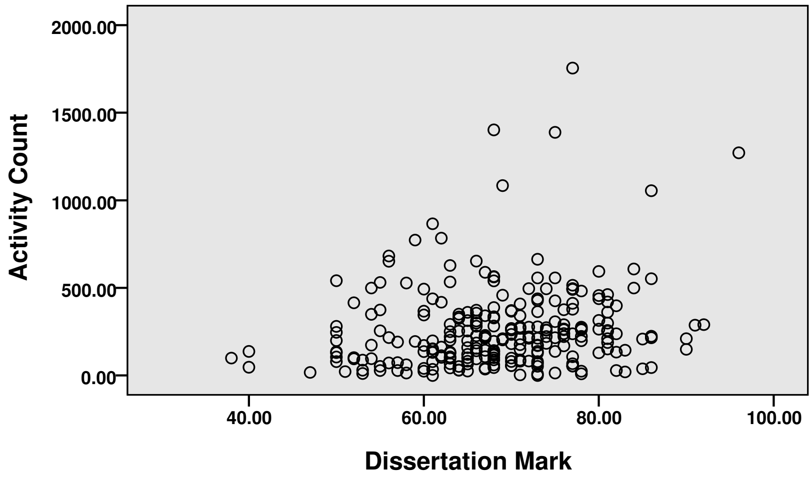
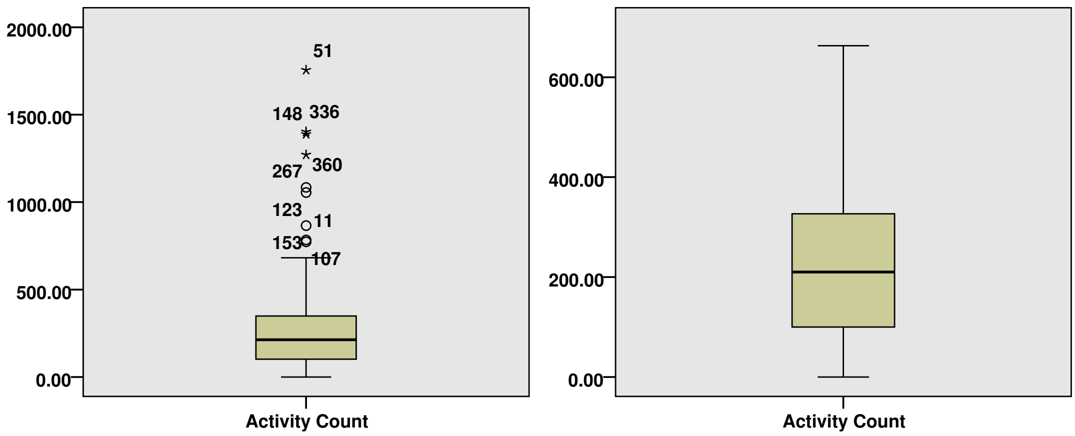


Figure 6.3.1: Scatter plot of system use (activity count) against dissertation mark



(a) Activity count with outliers (b) Activity count without outliers

Figure 6.3.2: Box plots of total student activity counts with and without outliers

results of this test verify the original finding: the total student activity count correlates positively and significantly with their dissertation mark ($r_s = 0.209$, $p = 0.001$). The resulting effect size is slightly higher with $r_s = 0.209$ excluding outliers compared to $r_s = 0.199$ including outliers.

Overall System Use Clusters

To examine the relationship between total system use and marks further, total system use can be used in a cluster analysis aimed at finding natural groupings (clusters) of cases based on variable characteristics, and the correlation test is then repeated using the newly created cluster variables instead of the total system use variable. In this study, four different cluster variables CV_i ($i = 1 \ldots 4$) with three clusters each were established using different clustering algorithms, three of which were the outcome of SPSS cluster analyses. This is to ensure that different ways of case assignment to clusters are used and that results based on these clusters are not biased. The distribution of cases over the three clusters of each variable is shown in Figure 6.3.3. The first cluster C_1 denotes low, the second C_2 medium, and the third C_3 high system activity.

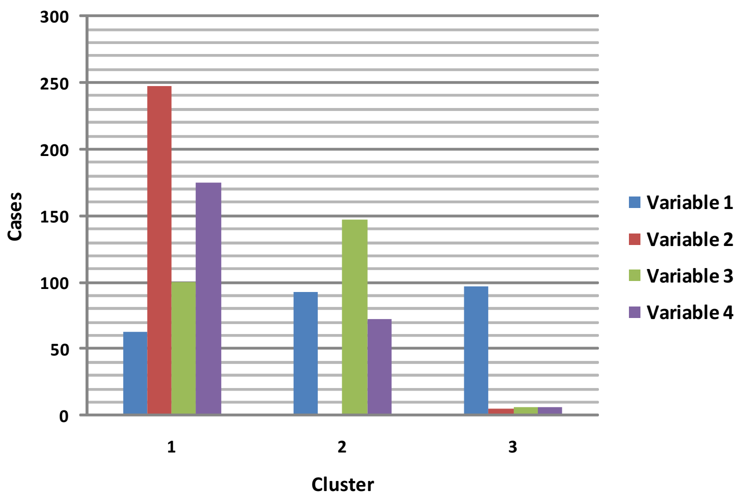


Figure 6.3.3: Comparison of cluster variable case distributions

Cluster variable 1 (CV_1) was established using the cumulative percentage of activity count value frequencies. For this purpose, a table was compiled listing all existing activity count values a in ascending order in the first column, the cases x_i in the data set X with the corresponding activity count in the second column, and finally the cumulative percentage z of activity count frequencies in the third column. Then, one selects the activity count values $A = \{a_1, a_2\}$ with $z(a_1) \approx 33\%$ and $z(a_2) \approx 66\%$ and makes them the cluster boundaries such that $C_1 = \{x_i \in X | 0 \leq a(x_i) < a_1\}$, $C_2 = \{x_i \in X | a_1 \leq a(x_i) < a_2\}$ and $C_3 = \{x_i \in X | a(x_i) > a_2\}$. In this context, $a(x_i)$ yields the activity count value for case x_i, and $z(a_i)$ the cumulative percentage of an activity count value a_i in the data set. This yields a distribution of 63 cases in C_1, 93 cases in C_2, and 97 cases in C_3.

Cluster variable 2 (CV_2) was obtained by applying a hierarchical single linkage nearest neighbour clustering algorithm. It is based on several hierarchical stages: at the first stage each case is assigned its own cluster. Then, clusters are linked using the nearest neighbour algorithm, that is, the similarity of each case with other cases (neighbours) is measured using the squared Euclidean distance, until only three clusters are left. Therefore, the distribution of cases over the clusters is based on the similarity of system activity count values, hence one gets 247 cases in C_1, 1 case in C_2, and 5 cases in C_3. Looking at the scatter plot in Figure 6.3.1, this result is not surprising: the five cases showing the highest system activity are in the third cluster, the one case with an approximate activity count of 1000 is in the second cluster, and the remaining cases are in the first cluster.

Cluster variable 3 (CV_3) was computed using a hierarchical Ward's method clustering algorithm. This algorithm is similar to the previous one as it uses a hierarchy of clusters which is gradually reduced to the desired number of clusters (three). However, Ward's method [Ward, 1963] measures the distance between cases using an analysis of variance, in other words, it endeavours to minimise the sum of squared errors (see section 5.6.3.1 for details). The result is a case distribution of 100 cases in C_1, 147 cases in C_2, and 6 cases in C_3.

Cluster variable 4 (CV_4) is the result of a k-means clustering algorithm with $k = 3$, which has the advantage of offering the means to form clusters which are as distinct as possible from each other. The algorithm starts off by forming k random clusters, then moves cases between clusters so that the variability *within* clusters is minimal and the variability *between* clusters maximal. This yields a distribution of 175 cases in C_1, 72 cases in C_2, and 6 cases in C_3.

Table 6.17: Correlations between activity cluster variables CV_i and student marks

		System Activity	CV_1	CV_2	CV_3	CV_4	Diss. Mark	Taught Mark
System Activity	r_s	1.0	0.937**	0.264**	0.861**	0.804**	0.199**	0.064
	p		0.000	0.000	0.000	0.000	0.002	0.314
CV_1	r_s	0.937**	1.0	0.178**	0.782**	0.757**	0.190**	0.047
	p	0.000		0.005	0.000	0.000	0.002	0.452
CV_2	r_s	0.264**	0.178**	1.0	0.306**	0.328**	0.138*	0.012
	p	0.000	0.005		0.000	0.000	0.029	0.856
CV_3	r_s	0.861**	0.782**	0.306**	1.0	0.576**	0.258**	0.079
	p	0.000	0.000	0.000		0.000	0.000	0.212
CV_4	r_s	0.804**	0.757**	0.328**	0.576**	1.0	0.086	-0.008
	p	0.000	0.000	0.000	0.000		0.174	0.904
Diss. Mark	r_s	0.199**	0.190**	0.138*	0.258**	0.086	1.0	0.641**
	p	0.002	0.002	0.029	0.000	0.179		0.000
Taught Mark	r_s	0.064	0.047	0.012	0.079	-0.008	0.641**	1.0
	p	0.314	0.452	0.856	0.212	0.904	0.000	

Looking for relationships between these cluster variables, the dissertation mark, and the taught mark, the results shown in Table 6.17 were obtained. As expected, all cluster variables correlate positively and significantly with the total system activity count, in other words, it is reasonable to say that the cluster variables accurately represent total system activity. However, the relatively low effect size ($r_s = 0.264$) of the hierarchical single linkage nearest neighbour cluster variable CV_2 compared to the system activity count shows that this relationship is weaker than that with other cluster variables. Furthermore, all cluster variables except for the k-means cluster (CV_4) correlate positively and significantly with the dissertation mark ($p \leq 0.03$). At the same time, there is no correlation between any of the cluster variables and the taught mark. These results support the assumption previously made, that is, that there is a positive and significant correlation between system use and post-test student performance.

To verify this assumption further, a comparison of dissertation mark means between clusters was conducted. Since system use is non-normally distributed, the non-parametric Kruskal-Wallis test was used to test for between-group effects. Afterwards, the non-parametric Mann-Whitney U test was applied to compare the lowest and the highest cluster (C_1 against C_3) of each variable except CV_4 which does not correlate with the dissertation mark. If system use really affected the dissertation mark, one would expect a significant increase between these two clusters. The results of both tests for each cluster variable are summarised in Table 6.18.

Table 6.18: Between-cluster effects on the dissertation mark

	Kruskal-Wallis			Mann-Whitney (C_1 vs. C_3)		
Cluster Variable	H	N	p	U	Z	p
CV_1	9.649	239	0.008	1894.5	-3.114	0.002
CV_2	4.785	239	0.091	291.0	-1.915	0.055
CV_3	17.832	239	0.000	4641.5	-3.628	0.000
CV_4	5.221	239	0.073	5464.5	-0.698	0.485

It shows that for cluster variables CV_1 and CV_3 there is a significant between-cluster effect, while no effect was found for the other two variables. In other words, the mean dissertation mark differs significantly between clusters 1 to 3 for variables CV_1 and CV_3. Furthermore, there is a significant difference in the mean dissertation mark between clusters 1 and 3 for these two variables, suggesting that students with high system activity (those in cluster 3) performed significantly better than those with low system activity (cluster 1).

6.3.2 System Use and Student Pass Rate

In order to test for a relationship between system use and student pass rate, two different techniques can be used. First, one can look at the correlation between project failure and system use, that is, only observations from one year are analysed regarding possible relationships. Second, it is also possible to compare total MSc programme statistics between two consecutive years (2009 and 2010). When using the latter technique, one should note that there are invariably differences between cohorts of different years, making this technique less accurate than the former one.

Definition 6.6. A student *passes* the course if their final mark is 50% or more, otherwise if their mark is less than 50% the student *fails* the course. Mathematically, failure can be expressed as

$$q_f(u) = \begin{cases} 0 & m_d \geq 50 \\ 1 & m_d < 50 \end{cases}$$

with m_d denoting the dissertation mark of student u in per cent. Consequently, q_f is a binary function yielding 1 for project failure and 0 for project pass. Conversely, pass can be expressed as $q_p(u) = 1 - q_f(u)$, that is, the inverse of the failure function $q_f(u)$.

Examining the correlation between total system use $s(u)$ and student failure $q_f(u)$ in 2010, one finds that student failure is negatively and significantly correlated with system use ($r_s = -0.164$, $p = 0.009$, $N = 252$) at the 0.01 level. Since $q_f(u)$ is binary, the true effect of this correlation is slightly higher with $r_b = -0.480$. In other words, failing students used the system less often than those who passed. This quite strong relationship is also depicted in the box plot in Figure 6.3.4 and also holds if all outliers are eliminated ($r_s = -0.163$, $r_b = -0.479$, $p = 0.011$, $N = 243$) using the procedure described in the previous section 6.2.1.

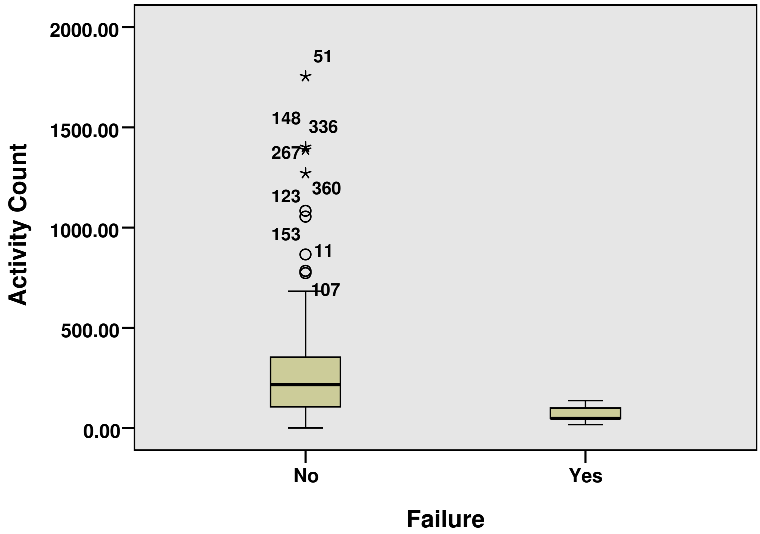


Figure 6.3.4: Box plot of student failure and system use with outliers

Applying the second technique, the means of the MSc programme results of the years 2009 and 2010 were taken and compared with each other using the independent t-test. First, for each student and each year, their MSc result was encoded such that 0 denotes failure and 1 indicates pass. This results in a mean of 0.93 for 2009 ($N = 146$, $\sigma = 0.253$) and 0.97 for 2010 ($N = 274$, $\sigma = 0.158$). Levene's test is significant ($F = 18.431$, $p < 0.01$) so that equal variances may not be assumed. The corresponding independent t-test comparing the two means is non-significant ($t = -1.863$, $p = 0.064$, $df = 206.615$), that is, one can assume that the number of failing students did not change significantly between years 2009 and 2010; however, it did represent a small effect $r = 0.129$. A detailed breakdown of the statistics is shown in Table 6.19. The decrease of failures from 6.8% in 2009 to 2.6% in 2010 accounts for the small effect size obtained as part of the independent t-test, but is statistically non-significant.

Table 6.19: Comparison of MSc results between years 2009 and 2010

	2009		2010	
Distinction	44	30.1%	68	24.8%
Pass	92	63.0%	199	72.6%
Fail	10	6.8%	7	2.6%
Total	146		274	

In summary, it can be concluded that hypothesis 5.2 holds when confining only to year 2010 data and looking at correlations between system use and student pass/failure. However, in comparison with historical data – here that of the previous year 2009 – no significant change to the number of students passing or failing their programme can be detected.

6.3.3 System Use and Perceived Project Management Capabilities

A relationship between student system use and perceived project management capabilities was examined using a Spearman correlation test looking for relationships between the total activity count, individual feature activity counts, and subjective feedback on feature and overall system helpfulness for project management provided by students in the closing questionnaire. More specifically, students were asked to rate the helpfulness of a number of features on a Likert scale (1 to 5). These features are dashboard (graphs and charts), student ranking table, news feed, email notifications, progress reports submitted by monitor and supervisor, event attendance feedback, task list, event and meeting organisation, data export, comments on group pages, and each of the graphs displayed on the dashboard. Furthermore, Likert scale ratings on student agreement with 5 general statements were obtained. These statements represent characteristics of good MSc project management.

1. The system helped keeping myself organised.
2. The system enabled me to communicate problems.
3. The system enabled me to keep contact with my monitor and supervisor.
4. The system helped me to get in contact with other students.
5. The system enhanced MSc project management.

The total student system activity count correlates positively and significantly ($p < 0.05$) with helpfulness ratings on student ranking ($r_s = 0.204$), progress reports submitted by their supervisor ($r_s = 0.256$), and event attendance feedback ($r_s = 0.202$). This shows that students who used the system more frequently also reported higher helpfulness ratings on the main system features ranking, progress reports, and event attendance

Table 6.20: Correlations between questionnaire items and student feature use

Survey Item	Feature Use (Activity Count)					
	Group page	Home page	News feed	Group comments	Project page	Dash-board
Helpfulness Ratings						
Progress reports (monitor)	0.241*	–	0.208*	–	–	0.230*
Progress reports (supervisor)	–	0.237*	0.213*	–	0.219*	0.242*
Event attendance feedback	–	–	–	0.196*	0.194*	–
Event organisation	–	–	0.212*	0.200*	–	–
News feed	–	–	–	–	0.194*	–
Ranking	–	–	0.360**	–	–	–
Dashboard	–	–	0.246*	–	–	–
Task list	–	–	–	0.233*	–	–
Agreement Ratings						
Helped keeping organised	–	–	0.212*	–	–	–
Helped problem communication	–	–	0.247**	0.248**	–	–
Helped keeping contact with monitor/supervisor	–	–	0.245**	–	–	–
System enhanced project management	–	–	0.233*	0.191*	0.199*	–

tracking. However, no significant correlations were found between student system use and agreement ratings on any of the 5 general statements listed above.

Table 6.20 shows existing significant correlations between feature use and closing questionnaire responses, while non-significant correlations are omitted to increase readability. Cells with a dash also refer to non-significant correlations between existing items mentioned in the table. Some interesting relationships are summarised here:

- Helpfulness ratings for progress reports submitted by monitors correlate positively and significantly with student activity on the group page. This can be explained by this page being the main virtual space for monitoring group meetings.

- Helpfulness ratings for progress reports submitted by supervisors, event attendance feedback, the news feed, and agreement to statement number 5 correlate positively and significantly with student activity on the project page. This page is the main entry point to all project-related activities.

- Helpfulness ratings for progress reports submitted by both monitor and supervisor correlate positively and significantly with dashboard use. One possible explanation is that charts displayed on the dashboard aggregate this information.

- News feed activity correlates positively (medium effect) and significantly with nearly all items in the Table 6.20. It seems that this feature had a high effect on perceived system helpfulness.

Another way of testing for an improvement in student project management capabilities is to examine possible relationships between system use, student progress ratings submitted on a weekly basis, and student performance. This approach assumes that students who used the system must have made better progress on their project – as a result of enhanced project management – and hence achieved a better mark on their dissertation. In other words, high progress ratings are believed to be an indirect indicator for good project and time management. In fact, a Spearman correlation test reveals that system use correlates positively and significantly ($p < 0.01$) with student-rated ($r_s = 0.214$), monitor-rated ($r_s = 0.213$), and supervisor-rated overall progress ($r_s = 0.253$); this constitutes a medium effect. Similarly, overall progress ratings of all user roles correlate positively and significantly ($p < 0.05$) with both the taught and the dissertation mark (see Table 6.21 for details), while effect sizes with the dissertation mark are generally higher (except for monitor ratings). This means that students with high taught marks also achieved higher overall progress ratings on average. Drilling down into the usage counts of individual system features, Table 6.21 shows that most positive and significant correlations exist with the event calendar, home page, the project page, and various visualisations of student progress metrics. This suggests that students using these features more often reported higher progress on average and also received higher progress ratings from their monitor and supervisor.

Finally, as outlined in section 2.3 on page 43, good project management is – besides other aspects – dependent on good time management. Therefore, an alternative way of testing the hypothesis was to look for improvement in students' ability to hand in their final MSc dissertation on time. For this purpose, data from years 2008, 2009, and the year of the study (2010) was examined regarding significant changes in the average number of days students handed in their dissertation late. Since the distribution of late submission days is non-normal for all three years (Kolmogorov-Smirnov test: $D(130) = 0.494$ with $p < 0.01$ for 2008, $D(151) = 0.501$ with $p < 0.01$ for 2009, and $D(256) = 0.427$ with $p < 0.01$ for 2010), the non-parametric Kruskal-Wallis test had to be used to analyse between-year differences. Its output shows that there is a significant change in the number of days students handed in their dissertation late between all three years ($H(2) = 17.742$, $p < 0.01$). For post-hoc pair-wise comparisons between years, several non-parametric Mann-Whitney U tests had to be applied. Doing this for more than one pair, however, results in Type I errors to build up, possibly beyond the critical value of 0.05. Therefore, the so-called *Bonferroni correction* must be applied, so that the maximum Type I error probability for multiple comparisons is made up by $p = \frac{0.05}{n}$ where n is the number of tests performed. For example, let there be 10 comparisons and assuming a confidence level of 95%, the minimum significance is $p = \frac{0.05}{10} = 0.005$, which is indeed very small. Therefore, one has to restrict the number of post-hoc Mann-Whitney tests to an absolute

Table 6.21: Correlations between progress metrics, system use, and marks

	Student Progress (Mean)			Student Motivation (Mean)		
	Student	Monitor	Supervisor	Student	Monitor	Supervisor
Activity Count	.214** .001	.213** .002	.253** .006	.186** .005	.214** .002	.259** .005
Taught Mark	.224** .001	.219** .002	.348** .000	.213** .001	.186** .008	.371** .000
Dissertation Mark	.357** .000	.167* .018	.455** .000	.338** .000	.143* .043	.503** .000
Feature Usage Correlations						
Event Calendar	.144* .031	.167* .017	.181 .052	.114 .089	.137 .053	.101 .280
Group Page	.082 .222	.222** .002	.212* .022	.055 .417	.198** .005	.224* .016
Home Page	.262** .000	.222** .002	.284** .002	.233** .000	.228** .001	.295** .001
Project Page	.210** .002	.151* .031	.249** .007	.196** .003	.145* .040	.223* .016
Task List	.117 .082	.101 .153	.203* .029	.070 .297	.088 .213	.183* .049
Attendance Chart	.168* .012	.143* .042	.173 .063	.193** .004	.140* .047	.198* .033
Performance Graph	.156* .020	.209** .003	.245** .008	.182** .006	.195** .005	.311** .001
Histogram Last Week	.201** .003	.208** .003	.288** .002	.155* .021	.211** .003	.314** .001
Histogram Current Week	.178** .008	.205** .003	.217* .019	.167* .012	.207** .003	.217* .019
Report Metrics Chart	.120 .073	.130 .065	.193* .038	.136* .042	.130 .066	.214* .021

minimum, otherwise the significance value becomes too small and thus too restrictive. Consequently, only three comparisons were conducted, namely between years 2008 and 2009, 2009 and 2010, and 2008 and 2010. Then, the Bonferroni correction was applied and all effects are reported at a $\frac{0.05}{3} = 0.0167$ significance level. The results are shown in Table 6.22, suggesting that there is no significant change between years 2008 and 2009, but that the average number of days students submitted their dissertation late rose significantly at the 0.0167 level between years 2008 and 2010, and 2009 and 2010. However, the effects are small ($r < 0.2$).

To rule out that these results are due to independent (and hence different) cohorts being compared, a related-samples comparison was conducted between late penalty days of two independent submissions and the dissertation submission of the same cohort in 2010. More precisely, all MSc students had to take a Research Methods module in the first term, and they also had to submit a project brief at the beginning of their summer project. The average late penalty days of these two submissions were then compared with those

Table 6.22: Pairwise comparisons of late dissertation submission days between years

Year 1	Year 2	μ_1	μ_2	N_1	N_2	N	U	Z	p	r
2008	2009	0.25	0.21	130	151	281	9689.0	-.0398	0.690	-0.024
2009	2010	0.21	0.66	151	256	407	16779.5	-3.533	0.000	-0.175
2008	2010	0.25	0.66	130	256	386	14670.0	-2.956	0.003	-0.150

of the final dissertation. Again, late submission days were non-normally distributed, so that the non-parametric Friedman ANOVA test had to be used. Its output suggests that there are significant differences in late penalty days between all three submissions ($\chi^2(2) = 8.808$, $p = 0.012$). Pairwise post-hoc comparisons were conducted using two Wilcoxon tests as shown in Table 6.23. The Bonferroni correction was applied and all effects are reported at a $\frac{0.05}{2} = 0.025$ level. It is shown that the average number of days students submitted late is significantly higher for the dissertation compared to the Research Methods coursework (with a small effect $r = -0.193$), while no significant difference was found between the project brief submission and the final dissertation.

Table 6.23: Pairwise comparisons of late submission days between in-course deliverables

Deliverable 1	Deliverable 2	μ_1	μ_2	N	T	p	r
Research Methods	Dissertation	0.40	0.55	236	701	0.003	-0.193
Project Brief	Dissertation	0.41	0.55	234	657	0.036	-0.137

In summary, a positive and significant relationship was found between overall system use and overall progress ratings submitted by all three user roles. Student use of features concerned with project management (home page, project page, charts and graphs) also positively affected their average progress ratings. The same relationship was found with helpfulness ratings for specific system features, namely ranking table, progress feedback by supervisor, and event attendance feedback. However, there is no significant relationship with any of the five main statements representing characteristics of good project management. Similarly, the average number of days students submitted their dissertation late is significantly higher in 2010 compared to previous years 2008 and 2009. This also holds for the comparison with the Research Methods coursework and project brief submission late penalties.

6.3.4 Feature Use, Motivational Effect, Perceived Helpfulness, and Weekly Ratings

Going beyond the test of single hypotheses, it is also useful to bring together statistics of feature usage, their perceived motivational effect, their perceived helpfulness for project management, and weekly progress and motivation ratings. For this purpose, blocks of related statistics are defined in order to analyse correlations between contained elements.

Charts, Graphs A positive correlation exists between perceived motivational effect and perceived helpfulness for project management ($r_s = 0.772$, $p < 0.01$). Furthermore, usage of these features correlates positively and significantly with self-rated, monitor-rated, and supervisor-rated student motivation and overall progress ($p < 0.01$, $0.188 \leq r_s \leq 0.251$).

Ranking Table There is a positive correlation between home page views and perceived motivational effect ($r_s = 0.271$, $p < 0.01$) as well as helpfulness ($r_s = 0.209$, $p < 0.05$), project page views and perceived motivational effect ($r_s = 0.290$, $p < 0.01$), and user profile page views and perceived motivational effect ($r_s = 0.333$, $p < 0.01$) as well as helpfulness ($r_s = 0.288$, $p < 0.01$) of the ranking table. It should be noted that the ranking table was displayed on these pages. Moreover, home page views correlate significantly with self-rated, monitor-rated, and supervisor-rated student motivation and overall progress ($p < 0.01$, $0.213 \leq r_s \leq 0.266$).

Progress Monitoring Positive correlations were found between views of the current week's performance histogram, perceived motivational effect as well as helpfulness of monitor and supervisor feedback ($0.268 \leq r_s \leq 0.331$, $p < 0.05$). Views of last week's performance histogram correlate positively with the perceived motivational effect of monitor and supervisor feedback with $r_s = 0.229$ and $r_s = 0.270$ ($p < 0.05$), respectively.

News Feed The perceived motivational effect of the news feed correlates positively and significantly with its perceived helpfulness for project management ($r_s = 0.767$, $p < 0.01$). Student usage of this feature also correlates with monitor-rated and supervisor-rated student motivation and overall progress ($p < 0.05$, $0.163 \leq r_s \leq 0.207$).

Email Notifications There is a positive correlation between perceived motivational effect and helpfulness for project management ($r_s = 0.747$, $p < 0.01$).

Event Attendance Feedback Views of the event attendance chart are negatively correlated with its perceived helpfulness ($r_s = -0.200$, $p < 0.05$), however, perceived helpfulness correlates positively with perceived motivational effect of that feature ($r_s = 0.507$, $p < 0.01$).

Meeting Organisation Perceived helpfulness of meeting organisation for project management correlates positively with student-rated overall progress ($r_s = 0.204$, $p < 0.05$). Also, student usage of the group page correlates positively with monitor-rated and supervisor-rated student motivation and overall progress ($p < 0.05$, $0.198 \leq r_s \leq 0.224$).

Monitoring Meetings Both the perceived helpfulness and frequency of monitoring meetings correlate positively with monitor-rated student progress with $r_s = 0.267$

and $r_s = 0.403$ ($p < 0.05$), respectively. This suggests that students making good progress also reported a higher helpfulness of monitoring meetings.

Task List The perceived motivational effect of the task list correlates with is perceived helpfulness for project management ($r_s = 0.691$, $p < 0.01$), average self-reported student progress ($r_s = 0.238$, $p < 0.05$), and monitor-rated student progress ($r_s = 0.219$, $p < 0.05$). Students who found this feature helpful also reported higher overall progress and received higher progress ratings from their monitors. Furthermore, student usage of the task list correlates positively and significantly with supervisor-rated student motivation and overall progress ($p < 0.05$, $0.183 \leq r_s \leq 0.203$). The task list is embedded into the project page, whose usage by students also correlates positively and significantly with self-rated, monitor-rated, and supervisor-rated student motivation and overall progress ($p < 0.05$, $0.145 \leq r_s \leq 0.249$).

Group Notes There exists a positive correlation between perceived motivational effect and helpfulness for project management ($r_s = 0.756$, $p < 0.01$).

In summary, there is no relationship between usage and perceived motivation/helpfulness for features progress charts, news feed, email notifications, task list, and group notes. However, students who reported these features to be motivating also found them more helpful for project management. In contrast, usage of the features ranking table, progress feedback, and event attendance feedback seems to have positively affected student motivation. In addition, charts and graphs, the home page including the ranking table, the task list and the project page, and the group page positively affected average weekly student motivation and progress ratings.

6.3.5 System Use Triggers

One question to be asked when looking at system use is "how was this user activity triggered?", or better "which system features caused users to become active on the system?". To answer this question, the relationships between *automatic* and *manual* system activity have to be analysed. Automatic activity denotes any system activity caused by the system itself, for example, services running in the background which indirectly affect user behaviour. In contrast, manual activity is caused directly by the user. Both types of activity are interlinked, in other words, automatic activity can trigger manual user activity on the system and vice versa.

A prominent example of automatic activity is email notifications. They originate from a background service running on the main web server containing an underlying workflow process which periodically checks whether an action should be taken by a particular system user in response to another user's activity or a particular project state. For example, the news feed email notification service periodically checks for new activity in groups and student projects and automatically informs associated users of any changes originating from that activity.

In fact, email notifications are strongly and significantly correlated with system use ($r_s = 0.978$, $p = 0.000$). The high effect size shows that this relationship is very strong and that nearly all system activity was down to the number of email notifications. Breaking down the total notification count into related features, correlation analysis finds positive and significant ($p < 0.01$) relationships between

1. The number of event reminder emails and event feature use ($r_s = 0.528$),
2. The number of event attendance feedback reminder emails and event attendance feedback submissions ($r_s = 0.525$),
3. The number of emails sent to students who repeatedly failed to attend meetings and event feature use ($r_s = 0.296$),
4. The number of news feed emails and event feature use ($r_s = 0.627$), event attendance feedback submissions ($r_s = 0.448$), data export use ($r_s = 0.687$), group page interactions ($r_s = 0.860$), home page interactions ($r_s = 0.945$), news feed interactions ($r_s = 0.647$), group note use ($r_s = 0.309$), project page interactions ($r_s = 0.943$), graphs and charts usage ($r_s = 0.994$), project task use ($r_s = 0.610$), and the total system use ($r_s = 1.000$).

What is more, student system use also correlates positively and significantly ($r_s = 0.324$, $p < 0.01$) with that of their monitor. This constitutes a medium effect size and indicates that monitor activity indirectly triggered student activity and vice versa.

6.3.6 Exploratory Factor Analysis

In order to identify *latent variables*, which are made up by one or more individual variables in the data set, an exploratory factor analysis was applied using principal components as a factor extraction method. As mentioned in section 5.6.3.6 on page 149, both factor and principal component analysis are very similar as for their underlying theory, however, the result obtained from a principal components analysis only applies to the data set used in the analysis, whereas that of other extraction methods allows more general interpretations but may produce ambiguous results.

In this work, factors were extracted using principal components because this method generally produces more interpretable and unambiguous results than other extraction methods. A total of 55 variables were used in the analysis, excluding those variables not correlating with any other input variables or where correlations were too low ($r \leq 0.1$) or too high ($r \geq 0.9$). From the resulting factors, those with eigenvalues greater than 1.0 were retained, all others were pruned and are not covered here. Also, variable factor loadings smaller than 0.4 were ignored, that is, if a variable's loading on a factor was found to be smaller than 0.4, it did not count towards the factor. To further optimise factor loadings, the Varimax rotation algorithm with Kaiser normalisation was applied to the resulting factor matrix, yielding a total of 14 factors summarised in Table 6.24. The Varimax rotation is the most popular of all rotation algorithms and aims to produce a few high-valued loadings and many low-valued loadings so that the number of variables per factor is minimal with each variable having a maximum loading with regard to that factor [Abdi, 2003]. Factor names were assigned based on the variables loading highly on factors and are explained in more detail in the next paragraph.

Table 6.24: List of factors F_1 to F_{14} and their assumed meaning

F#	Name	Short Name	Variables	Description
1	Student Activity	STA	10	Hits on system pages and charts
2	Monitor Activity	MA	5	
3	Supervisor Activity	SVA	5	
4	Weekly Feedback	FB	5	Average weekly ratings and feedback comments
5	Monitor-Student Interaction	MSA	5	Use of features enabling students and monitors to interact
6	Performance Chart Activity	PCA	3	Hits on charts depicting performance, attendance, and qualitative feedback over time
7	Supervisor-Student Interaction	SSA1	4	Use of features enabling students and supervisors to interact
8	Student Self-Evaluation	SE	3	Self-rated average weekly progress and motivation and feedback comments
9	Supervisor-Student Interaction in Project Groups	SSA2	2	Use of group comments and student tasks
10	Task Chart Activity	TCA	3	Hits on charts depicting task progress
11	Negative Feedback	NFB	3	Recommendations, negative remarks, and questions/answers in feedback comments
12	Qualitative Monitor Feedback	QMF	2	Average ratings of report body and appendix quality submitted by monitors
13	Detailed feedback	DFB	2	Provision of status reports and average supervisor-rated report body quality
14	Peer support	PS	2	Use of group notes and success stories in user feedback

Factors 1 to 3 (student, monitor, and supervisor activity) were identified as such since they only contained feature use count variables and all factor loadings were grouped by user role. Factor 4 was named "weekly feedback" because mean supervisor and monitor-reported student progress and motivation variables as well feedback comment aspects loaded high on that factor. In contrast, factor 5 was slightly more difficult to name. It is made up by feature use variables of students and monitors, in particular by those of features tasks, group, group comments, and news feed. Since these are the only features which can be used by both students and monitors for interacting with each other, the name "monitor-student interaction" seemed suitable. This also applies to factor 7, which was named "supervisor-student activity", for the same reason. Factor 6 shows high loadings of variables related to charts depicting student performance, that is, development of student progress, motivation, and report metrics over time, and also the weekly event attendance rate. Factors with less than 3 variables are difficult to interpret.

To enable further analysis with the data set using factors rather than variables, factor scores were saved in the data set using the Anderson-Rubin method as recommended by Field [2009]. This method ensures that there are no correlations between factor scores. The use of the Regression method, which does not give such a guarantee, yielded similar results and will not be covered in this section. In practice, a new factor variable and a value for each case is created denoting its score with regard to the factor represented by the new variable.

In the next step, factor scores can be used to analyse correlations between factors and other variables in the data set. Since the main objective is to find relationships with academic performance, a correlation test was applied looking for such relationships. The results are shown in Tables 6.25 and 6.26.

Table 6.25: Correlations between factors F_1 to F_7 and marks

Mark	F_1	F_2	F_3	F_4	F_5	F_6	F_7
Dissertation	.255*	-.218	-.063	.394**	-.049	.020	-.204
	.025	.056	.588	.000	.670	.862	.075
Taught	.178	-.293**	.014	.232*	-.196	.053	-.084
	.122	.010	.906	.042	.088	.648	.470

Table 6.26: Correlations between factors F_8 to F_{14} and marks

Mark	F_8	F_9	F_{10}	F_{11}	F_{12}	F_{13}	F_{14}
Dissertation	.404**	-.275*	.030	-.101	.140	-.132	-.138
	.000	.015	.797	.381	.225	.253	.232
Taught	.263*	-.169	-.005	-.043	.259*	-.037	-.040
	.021	.141	.964	.709	.023	.751	.733

The tables reveal some interesting relationships between factor variables and dissertation as well as taught student mark:

- Factor 1 (student activity) correlates positively and significantly with the student dissertation mark, while there is no correlation with their taught mark. This is no surprise as it verifies the findings in section 6.2.1, that is, the positive relationship between total activity count and student performance.
- The result for factor 2 (monitor activity) – a negative correlation with students' taught mark – is difficult to interpret. It seems to indicate that monitors of students with lower taught marks were more active on the system. As mentioned before, students' taught mark was used for monitoring group allocations on some occasions, which might have led to this result. Another possible interpretation is that monitors of weaker students provided more support through the system, hence the higher system usage.
- Factor 3 does not correlate with either mark.
- Weekly feedback (factor 4) correlates positively and significantly with both marks. This verifies earlier findings suggesting that students with high taught marks received higher weekly ratings on average, and students with higher ratings obtained a higher overall project mark.
- Factors 5 to 7 do not correlate with either mark.
- The findings for factor 8 (student self-evaluation) suggest that students could accurately evaluate their own performance and motivation and that this evaluation is reflected in their marks.
- Supervisor-student interaction in project groups (factor 9) is negatively correlated with the dissertation mark. Again, this result is hard to interpret, possibly on the grounds that the factor is made up by only two variables, namely use of group comments/notes and student tasks. The combination of these two usage metrics is usually only found in project groups where a supervisor actively manages a number of students in the same topic area, however, the underlying factor meaning might be completely different.
- Factors 10, 11, 13, and 14 are not correlated with either mark.
- Factor 12 (monitor-rated report quality metrics) correlates positively with the taught mark while no relationship was found with the dissertation mark. This seems to indicate that students with high marks in the taught part of their MSc also gained higher report quality ratings from monitors. In order to verify this, a separate correlation test was applied to the average report metrics submitted by both supervisors and monitors and student marks. The outcome does not support

the result for factor 12: both average monitor-rated report body and appendix quality do not correlate with either mark, whilst there are significant and positive correlations between supervisor-rated quality metrics and both marks (report body: $r = 0.278$ with dissertation and $r = 0.253$ with taught mark ($p < 0.01$); report appendix: $r = 0.192$ with dissertation and $r = 0.232$ with taught mark ($p < 0.05$)). Hence the underlying meaning of the factor might be different from the one assumed here.

In summary, the exploratory factor analysis was not particularly helpful in identifying latent variables, or put differently, it was hard to interpret the meaning behind these variables. Consequently, it was also difficult to make any meaningful conclusions based on the resulting factors and their correlations with other metrics, and where such interpretations could be made they may well be inaccurate or wrong.

6.3.7 Event Attendance

As part of the monitoring scheme, monitors were required to record their students' attendance for every group meeting. Based on this data, this section answers the question whether meeting attendance had any effect on the final project mark, overall student progress, and student motivation. Meeting attendance, monitor-rated mean student progress, monitor-rated mean student motivation, and the dissertation mark are all normally distributed ($df = 58$, $p > 0.05$) with $D = 0.103$, 0.069, 0.109, and 0.070, respectively. Correlation tests were used to analyse possible relationships between attendance and any of the other variables. Significant correlations were only found between:

- Attendance and monitor-rated student progress (Pearson correlation test, $r = 0.532$, $p < 0.01$)
- Attendance and monitor-rated student motivation (Pearson correlation test, $r = 0.590$, $p < 0.01$)

These correlations are very strong with effect sizes between 0.5 and 0.6, and can be explained by monitors rating students' progress and motivation based on their reports during weekly meetings. In other words, if students did not attend monitoring meetings, monitors would submit a "not seen" rating. What is more, attendance in supervision meetings does not seem to affect supervisor-rated progress and motivation. The results also show that here is no indication for existing relationships between meeting attendance and the final dissertation mark.

6.3.8 Predicting Failing Students

Another area of interest is the use of all findings presented so far for predicting students who are likely to struggle in their MSc project based on some of the metrics collected by the monitoring system. Particularly helpful are metrics which were found to be related to the final dissertation mark, for example, by correlation. They are then used as input variables (independent variables) of a suitable mathematical model, yielding the actual prediction as an output variable. This output variable is the dependent variable, for example, the dissertation mark or a binary flag denoting student failure or success.

One way of achieving this is to create a regression analysis resulting in a simple mathematical model fitted to the input data (predictor variables) which yields the output variable. Regression analysis always produces a linear model, that is, it tries to fit a straight line to the data (input variables) using the method of least squares. To do this, the algorithm first assumes the simplest model available which is based on the mean of variables. It then measures the vertical difference between the line and the actual data points and then changes the slope and the intercept of that line so that the sum of squared differences is minimal, that is, the error between the model (the line) and the actual data is minimised. In this process, the total sum of squares and the model sum of squares is used to produce R^2, whereby $R = \sqrt{R^2}$ is equivalent to the Pearson correlation coefficient which gives a good account of how well the model fits. In case there is more than one predictor variable, the model goes beyond a simple line and becomes multi-dimensional. It is then called a multiple regression model as opposed to a simple regression model with only one predictor variable.

Based on past results from various correlation tests, the following 8 variables seem to be suitable predictors going into the model:

- The total activity count s (1 variable). A model was also created using the weekly activity count, but was not found to be different from the one using the absolute activity count.
- The average self-rated, monitor-rated, and supervisor-rated overall student progress (3 variables): p_S, p_M, p_{SV}
- The average self-rated, monitor-rated, and supervisor-rated student motivation (3 variables): m_S, m_M, m_{SV}
- The taught mark a_t (1 variable).

Suitable in this context means that past analyses have shown that these variables are somehow related to the final dissertation mark. What is more, they meet the general assumptions regarding type (quantitative or categorical with at least 2 categories), variance (non-zero), linearity (linear relationship between predictors and outcome), etc. The outcome variable was chosen to be the dissertation mark a_d. Its predicted value can then be used to identify students which are likely to fall into a failing grade range. All variables were entered using the forced entry method, that is, the order of the predictors in the list of input variables is not taken into account when the model is created. Due to missing values, only $N = 80$ cases were valid and used in the model, which is made up by the following linear equation:

$$a_d = -3.37 + 0.001 \cdot s + 2.22 \cdot p_S - 0.11 \cdot p_M - 0.34 \cdot p_{SV} + 0.53 \cdot m_S - 0.46 \cdot m_M + 5.07 \cdot m_{SV} + 0.78 \cdot a_t \quad (6.3.1)$$

In order to test if this model is accurate and whether it generalises, a number of criteria must be met. The process of testing the model against these criteria is called *cross-validation*:

1. The difference between R^2 and the adjusted R^2 should be relatively small. The adjusted R^2 accounts for how well the model generalises beyond the sample population. In SPSS, R^2 was given as 0.728 and the adjusted R^2 as 0.697. The difference of 0.031 is relatively small so that this criterion is met.

2. The significance of R^2 can be tested using an F-ratio which is dependent on the number of cases N and predictors k used in the model ($N = 80$, $k = 8$). Sometimes, more than one possible model is generated whereby some predictors are excluded. This is normally the case when a sub-set of the predictors can accurately predict the outcome. Consequently, the more interesting measure is how F changes between different hierarchical models. In this case, only one model was produced and hence F itself is the change. SPSS produced $F = 23.755$ with $p < 0.01$, meaning that the change of F is significant.

3. In order to assess whether the final model is more accurate than just using the mean as a model, SPSS performs an ANOVA (analysis of variance) test. In this case, the ANOVA test was significant ($p < 0.01$) with $\mu^2 = 861.592$, $df = 8$, and $F = 23.755$.

4. No variables were excluded in the model creation process, indicating that all variables were necessary to predict the outcome.

5. Errors must be independent. To test this, the algorithm checks if any residuals are correlated. Residuals are the differences between the outcome predicted using the model and the actual (desired) values in the data set. SPSS uses the Durbin-Watson test [Durbin and Watson, 1951] to check whether errors are independent. It produces an output d, whose interpretation is dependent on the number of samples and predictor variables used. Values less than 1 and greater than 3 are clearly abnormal and indicate that there is a problem with the model. More specifically, for the model in question with $N = 80$ and $k = 8$, the lower and upper bound at a 5% significance level are 1.45262 and 1.83077 [Durbin and Watson, 1951], respectively. If d is lower than the lower bound, the residuals are positively correlated, otherwise if d is greater than the upper bound they are negatively correlated. The model

summary (see Table 6.27) states a value of 2.348 for d, which is clearly greater than the upper bound, denoting that there is a negative correlation between residuals of the model. However, since the value is well below 3 and relatively close to 2, there is no cause for concern.

Furthermore, there are several other guidelines which should apply for a model generalising beyond the sample population. In particular, the predictor variables should not strongly correlate with each other; if they do this is called *multicollinearity*. To identify whether this is the case for a set of predictors, SPSS produces an output called the *variance inflation factor* (VIF). The VIF is calculated for each predictor in the model and its value should be less than 10. Furthermore, the average of the VIF values of all predictors should not be significantly greater than 1, otherwise the regression may be biased. Another diagnostic value used in detecting problems in the model is the *tolerance* defined as $\frac{1}{\text{VIF}}$. A tolerance value below 0.2 suggests that there is a possible problem and values under 0.1 denote a serious problem with the model. The model output produced by SPSS is shown in Tables 6.27 to 6.28 and Figure 6.3.5.

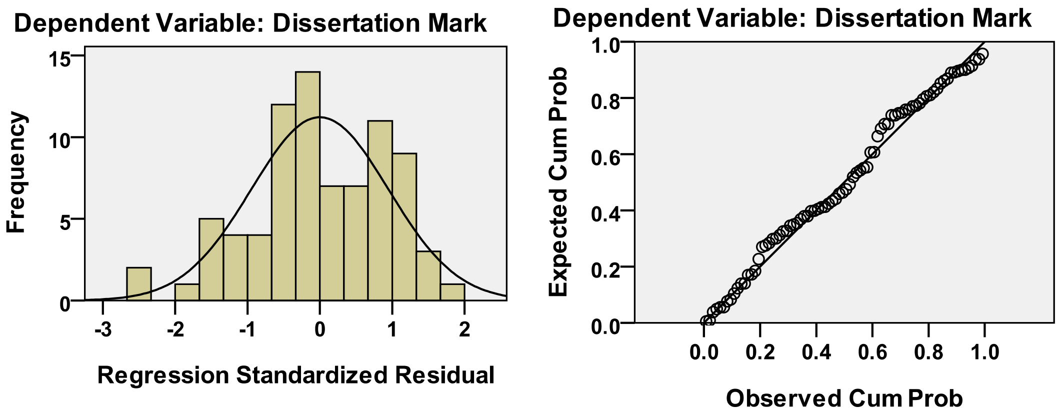
Table 6.27: Model summary

R	R^2	Adj. R^2	SE of Estimate	Change Statistics					Durbin-Watson (d)
				R^2 Change	F Change	$df1$	$df2$	p of F Change	
.853	.728	.697	6.02251	.728	23.755	8	71	.000**	2.348

Table 6.28: Model coefficients

Model	b	β	t	p	Tolerance	VIF
(Constant)	-3.365		-.546	.587		
Activity Count/System Use s	.001	.035	.517	.607	.858	1.165
Progress (Self-Rated) p_S	2.215	.166	1.213	.229	.204	4.891
Progress (Monitor-Rated) p_M	-.105	-.011	-.056	.955	.106	9.422
Progress (Supervisor-Rated) p_{SV}	-.335	-.028	-.186	.853	.173	5.782
Motivation (Self-Rated) m_S	.527	.039	.298	.767	.226	4.434
Motivation (Monitor-Rated) m_M	-.460	-.049	-.258	.797	.108	9.231
Motivation (Supervisor-Rated) m_{SV}	5.065	.409	2.756	.007	.174	5.747
Taught Mark a_t	.781	.537	7.879	.000	.823	1.215

Table 6.28 lists the model coefficients used with each of the predictor variables in Equation 6.3.1. One distinguishes between unstandardised and standardised coefficient values, denoted by b and β, respectively. The unstandardised values are dependent on the unit of measurement of the corresponding predictor, hence they are used in the model equation, while standardised values are useful for determining how "important" each variables is regarding the overall prediction (the output), hence they are independent of the unit of



(a) Residual distribution (histogram)

(b) Residual P-P plot

Figure 6.3.5: Residual plots from SPSS

measurement. The slope of the regression is denoted by t, and p indicates the significance of the contribution of each variable to the model. Finally, the table also lists the tolerance and VIF values for each coefficient; the meaning of these measures was explained earlier.

The model given by Equation 6.3.1 violates some of the cross-validation guidelines given above. Firstly, although the VIF value of each predictor is less than 10, their overall average is 5.236, which is significantly greater than 1, suggesting that the regression is biased. Secondly, the tolerance values for monitor-rated and supervisor-rated progress and motivation are less than 0.2, indicating a potential problem with the model. However, the residuals histogram (Figure 6.3.5a) and P-P plot (Figure 6.3.5b) indicate that residuals are normally distributed, which suggests that there are no model abnormalities.

What is more, the significance values p in Table 6.28 show that only two of the 8 predictor variables make a significant contribution to the model, namely the taught mark a_t and the supervisor-rated motivation m_{SV}. The relationship between each predictor and the model prediction (the outcome variable) can be gleaned from their β-values. They show that the taught mark (0.537) and supervisor-rated motivation (0.409) are most important for the overall prediction of the dissertation mark, followed by the student-rated progress (0.166) and the total student system use (0.035). SPSS also produces a table of "extreme" cases, that is, cases in the data set where the model prediction significantly deviates from the actual outcome. There are 2 extreme cases, constituting only 2.5% of all 80 cases.

In summary, a multiple regression model was used to predict the dissertation mark from 8 predictor variables selected after careful consideration of their relationship with the outcome variable (the dissertation mark). While the model seems to be robust and reasonably accurate, its cross-validation casts doubts on its prediction generalising beyond the sample population. In particular, the criteria for multicollinearity were violated as the VIF and tolerance values produced by SPSS show. Furthermore, the significance values for predictor contributions to the model are unsatisfactory. Of the 8 predictors used in the model, only two turned out to be significant contributors.

6.4 Discussion

Earlier, the design and architecture of a web-based MSc project monitoring system were presented. The system was designed to support self-regulated learning by providing features for technology-supported learning aspects (TSLAs) motivation, time management, progress awareness, and monitoring in the context of MSc summer projects in the School of Electronics and Computer Science (ECS) at the University of Southampton (UK). In particular, motivation was implemented using progress and event feedback features, charts and graphs visualising that data, a ranking table, and email notifications. Time management is represented as a set of project planning tools such as a task list, an event calendar, and a virtual project and monitoring group page. Progress awareness is achieved by means of progress visualisations (charts, ranking table) and user activity visualisations (news feed and news feed emails). Finally, monitoring was supported by progress and event feedback tools for students, monitors, and supervisors, and comments on the virtual group page. Similarly, the system was used in combination with a monitoring scheme which had proved helpful in a small-scale trial back in 2009, whereby each MSc student was assigned a project monitor in addition to the usual academic acting as their supervisor. Monitors and students met in groups about every week, discussing technical problems or other issues in a more informal atmosphere. The aim was to provide peer support and technical guidance and to disburden supervisors of less important project tasks. The monitoring system was used to report all this back to both the student and their supervisor, and to keep a record of student progress and motivation throughout the project. The system was also designed to support four out of the seven principles for good practice in undergraduate education devised by Chickering and Gamson [1987]. The relationship between self-regulated learning, technology-supported learning aspects analysed in this work, and the seven principles is depicted in Figure 6.4.1 and will be explained in the following sections in the context of the three main hypotheses. In the figure, the principles which are not directly supported are greyed out.

A quasi-experimental study was conducted using the monitoring system over a 17-week period in the 2009/10 academic year in the School of Electronics and Computer Science (ECS) at the University of Southampton. In total, 290 students in electronics or computer science, 19 monitors, and 69 academic staff (supervisors) participated in this study, producing an extensive data set containing 719 variables. This data was used in combination with subjective user feedback obtained from the closing questionnaire and semi-structured informal interviews in three different monitoring groups. The analysis was conducted using correlation tests because – as mentioned – experimental groups could not be created due to school policy restrictions and ethical concerns: every student in the school should be able to use the system and benefit from it. Therefore, the

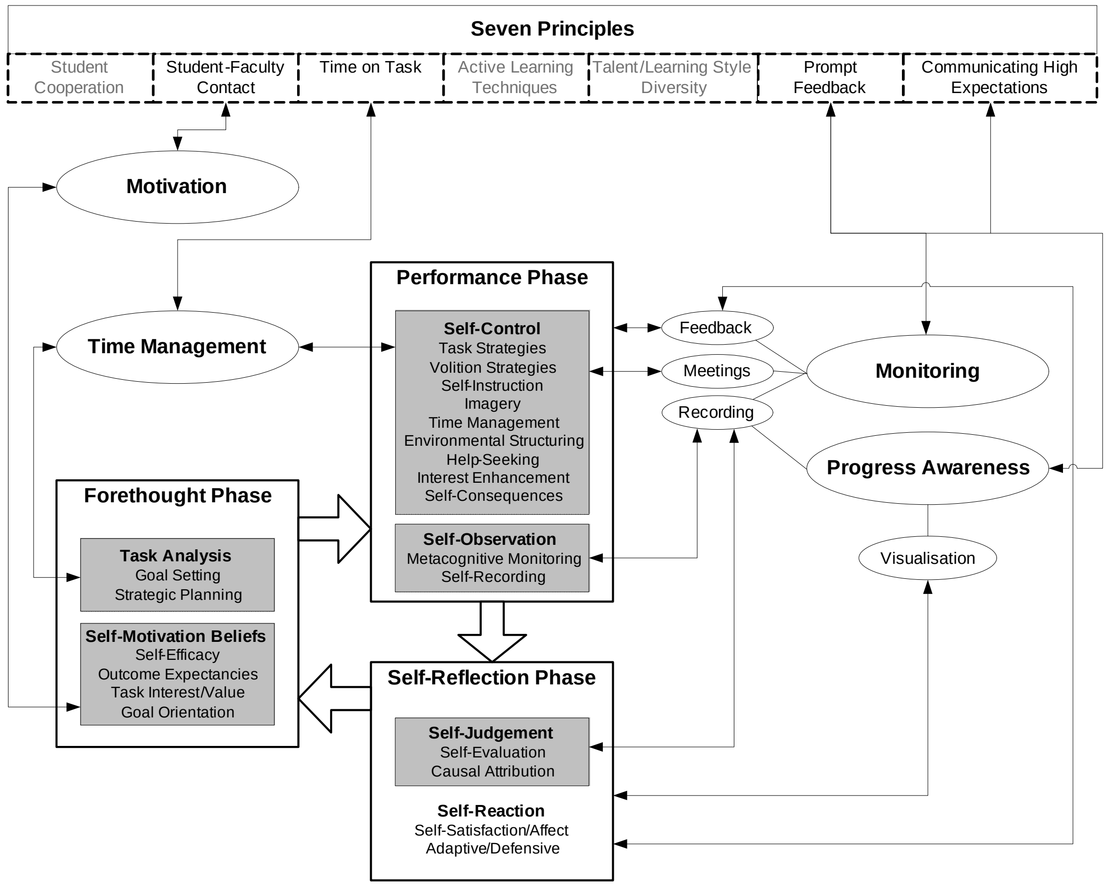


Figure 6.4.1: Relationship between the model of self-regulated learning proposed by Zimmerman [2011] (forethought, performance, and self-reflection phase), technology-supported learning aspects (oval shapes), and Chickering and Gamson's [1987] seven principles (top).

study was more observational than experimental, although tests for comparing means were used in some cases to find significant differences between groups of system users. All tests were conducted using the SPSS standard software package following Field's [2009] comprehensive text in this area, and all necessary caution was taken to ensure that the correct tests were applied on the data. For example, where variables turned out to be non-normally distributed, non-parametric tests less susceptible to such abnormalities were used.

Threats to the Study

Before the main research hypotheses and associated results are discussed in detail, the reader is reminded that all assumptions made here are solely relevant in the context of the study sample population. Results and interpretations thereof may not generalise beyond that population and a follow-up study may be necessary to verify them. Furthermore, the effects were only measured in the disciplines electronics and computer science in ECS and may not hold for samples from other disciplines, departments, or institutions. A linear regression analysis (see section 6.3.8) for predicting the student dissertation mark suggests that the resulting linear model does not necessarily allow a prediction beyond the sample population. This was verified using cross-validation techniques. Furthermore, the only relevant predictors turned out to be the taught mark and supervisor-rated student motivation.

This section is structured as follows: first, results of analyses conducted in the context of the main research hypotheses presented in section 5.3 on page 119 are discussed. This is followed by a discussion of the impact of features relative to learning aspects on self-regulated learning and a concrete narrative study using three example students.

6.4.1 Main Research Hypotheses

The three main research hypotheses presented in section 5.3 on page 119 focus on the effect of system features supporting technology-supported learning aspects of self-regulated learning (Hypothesis 5.1), the suitability of such features for supporting four of Chickering and Gamson's [1987] seven principles (Hypothesis 5.2), and the effect of the monitoring scheme in combination with system use on student behaviour (Hypothesis 5.3). Generally, the emphasis of this research is on *student* benefit, although subjective feedback of monitors was also presented. Future research may want to look at the specific benefit to other roles (monitors, supervisors).

The main results suggest that there is at least partial evidence in favour of all three hypotheses. The following sections will discuss each hypothesis separately, stating evidence for and against it, and providing alternative interpretations of the results where applicable.

6.4.1.1 Hypothesis 1

It is hypothesised that system features designed to support technology-supported learning aspects of self-regulated learning (see section 2.7 on page 68) positively and significantly affect student motivation, progress, and performance. An outline of these system features was provided earlier (in section 5.5.4 on page 139) but is repeated here for convenience: (i) motivation is supported by features progress/event attendance feedback, visualisations (charts), the ranking table, and email notifications, (ii) time management is implemented as a set of management tools such as the task list, the event calendar, and the virtual group as well as project page, (iii) progress awareness is designed as a set of visualisations (charts), the ranking table, the news feed, and email notifications, and (iv) the monitoring scheme is supported by features progress/event attendance feedback and comments on group pages. These learning aspects are directly represented in the model of self-regulated learning [Zimmerman, 2011].

Before results regarding these learning aspects are discussed, an important point must be made. Generally, correlations presented in section 6.2 should be seen as bidirectional relationships between variables, that is, further information is required to make more accurate statements about a directional relationship. For example, in section 6.2.1, which analyses correlations between feature use and student performance, progress, and motivation, relationships can be interpreted in two ways: either usage affected student performance or performance affected student usage. In order to gather further evidence indicating a possible correlation direction, one can look at correlations between different indicators of student performance, in this case (i) students' taught mark and (ii) their dissertation mark. Both marks strongly and positively correlate at the 99% confidence level, indicating that students with high taught marks also received higher dissertation marks. At the same time, both feature and overall system use do not correlate with the taught mark, which indicates that students who performed well on the taught part of their programme did not necessarily use these features more often. Although there are various different factors which could have affected students' dissertation mark such as monitoring meetings, group dynamics, etc., and taking the missing relationship between system use and the taught mark into account, one can be more confident that overall system use as well as the use of some particular features had some effect on student performance.

Motivation In self-regulated learning, motivation is a key aspect of the forethought phase, in which learners perform a learning task analysis and establish their self-motivation beliefs, determining the learner's initiative, perseverance, and adaptation with regard to their learning tasks. It is dependent on four factors, namely the learner's self-efficacy, their expectancies with regard to the task outcome, their interest in the task and its perceived value, and the learner's goal orientation:

1. A learner's self-efficacy is the belief in their own capabilities to master the learning task and determines the learner's choice of task, the effort they make on the task, the level of persistence, and finally their achievement. It is based on their ultimate learning goal, and available information about their peers' problem solving abilities as well as task progress.

2. While self-efficacy refers to the learner's beliefs in their own capabilities, outcome expectancy refers to the learner's beliefs in the result of their actions on a task. For example, students who belief that higher study effort will lead to higher task achievement are likely to be more motivated.

3. A learner's interest in the task is dependent on the perceived value of the task. The task value, in turn, is based on factors such as cost (consequences of pursuing the task such as time or effort), usefulness (functional task value), intrinsic value (immediate enjoyment attained from task engagement), and importance (perceived competence) [Zimmerman, 2011].

4. Goal orientation is defined as "different ways of approaching, engaging in, and responding to achievement situations" [Pintrich and De Groot, 1990]. One distinguishes two types of goal orientation: learning goal orientation and relative ability goal orientation. The former refers to the learner focussing on learning the material, while the latter refers to students who are focussed on showing their ability in relation to other learners. Relative ability goal orientation is therefore dependent on the availability of information about other learners' abilities and progress. Both types are claimed to positively affect self-motivation beliefs [Pintrich and De Groot, 1990; Wolters et al., 1996].

Prior research has established that learner's self-motivation beliefs influence their behaviour in the learning process. For example, unmotivated students are more likely to procrastinate and achieve good academic performance [Zimmerman, 2011].

Against this background, a set of features was introduced in the web-based monitoring system, aimed at positively influencing students' self-motivation beliefs. More specifically, progress and event attendance feedback were provided to enable students, monitors, and supervisors to submit frequent reports on quantitative and qualitative metrics representing students' MSc project progress and their motivation. These metrics were visualised in various ways: a set of charts and a ranking table enabling students to compare themselves with other students in their monitoring group or studying on the same programme. This was complemented by a news feed and email notifications prompting user action and raising their awareness of other (associated) users' activity on the system.

If the use of these features by students was to have a positive effect on their motivation, one would expect the following relationships:

- The provision of weekly progress feedback by students makes them reflect on the progress of their project. This can be contrasted with progress feedback submitted by their monitor and supervisor: students receive feedback from two external sources, whose feedback might not necessarily match their self-assessed progress. Depending on the discrepancy or similarity of such feedback, the student's self-efficacy, outcome expectancies, and task interest might change. For example, negative feedback from their supervisor might result in the student doubting their ability to master the task and re-assessing the cost of the task, its intrinsic value, and its importance.

- The provision of weekly motivation by students enables them to reflect on their self-motivation beliefs – or on what they think this is. The assessment of motivation comes with several issues:

  - People might have different definitions of motivation and hence rate it differently. Let m_1 be the student's perception of their own motivation, m_2 the monitor's, and m_3 the supervisor's perception of the student's motivation with $m_i \in \mathbb{N}$ and $m_i \in [1, 5]$, then it is likely that each m_i will differ slightly just as perceptions and definitions differ between users. Descriptive statistics presented in section 6.1.3 on page 155 show that the average of students' own motivation ratings per project week was very similar to their supervisor's perception with very few exceptions (the eighth project week, for example), while their monitor's perception was at times different from their own. This was also verified using a correlation test (see section 6.2.1.2). One possible explanation lies in the nature of MSc projects in general: supervisors have much more frequent and intense contact with their students, and they have years of experience in supervising MSc projects. In summary, it seems that supervisors and students have a very similar perception of student motivation, while monitors do not.

- Rating motivation on a scale from 1 to 5 might be too simplistic. This is certainly a weak point. Most motivational models come with extensive questionnaires used to measure motivation on different scales and in different dimensions. Undoubtedly, a huge number of psychological instruments for measuring motivation exists (see section 2.2 on page 26), most of which have not been thoroughly evaluated. However, using long questionnaires and making all users complete them every week was simply infeasible and would have been counterproductive. Furthermore, the Likert scale is widely used in a variety of different contexts and it is anticipated that users are familiar with it.
- Motivation ratings were submitted once a week, but might change much more frequently. This is obviously true, but not relevant in the context of this study. The focus is not on the precise measurement of student's motivational state at all times during the study but merely on the use of such ratings for different visualisations, which are in turn aimed at raising student progress awareness, itself a facilitator of motivation. Furthermore, the overall average of ratings per student at the end of the project was used in correlation analysis with system use and student performance indicators (marks), and the average of ratings in 4-week blocks in repeated measures analysis for the purpose of detecting general statistically significant trends.
- Motivation is a subjective measure. Therefore, all results presented here and all interpretations provided must be treated accordingly, that is, they are less robust than results based on objective measures.

• Feedback visualisations are aimed at enabling students to compare themselves with their peers, affecting their relative ability goal orientation and providing information about their progress in relation to others, hence also affecting their self-efficacy.

- Similarly, the news feed and email notifications are provided for the purpose of raising students' awareness of their peers' project progress. This is also expected to affect students' self-efficacy, outcome expectancy, and relative ability goal orientation.
- Since motivated students are claimed to be more persistent and procrastinate less on their learning tasks, they are likely to make better progress and achieve higher academic performance.

The analysis of collected data yields strong evidence in favour of these features positively affecting student progress, motivation, and performance (dissertation mark). The use of progress feedback positively affected student's dissertation mark as well as their average weekly progress and motivation ratings submitted by themselves, their monitor, and their supervisor. In contrast, submissions of event attendance feedback only affected self-rated, monitor-rated, and supervisor-rated average project progress and monitor-rated average student motivation ratings; the dissertation mark remained unaffected.

The use of features visualising weekly feedback also positively affected student performance and progress as well as motivation ratings submitted by all three user roles. More specifically, these features were (i) histogram charts depicting last and current week's distribution of progress and motivation ratings in the cohort including a marker indicating the current user's position, (ii) a graph plotting these metrics over time and also showing the average in the cohort, and (iii) a ranking table, which was displayed on the home page, the project page, and the group page. Use of the former two pages correlates positively and significantly with student performance, progress and motivation. Unfortunately, no direct usage statistics for the ranking table could be collected since direct user interaction with this feature was not possible. However, it was displayed in a prominent place on all of these pages.

Furthermore, student interactions with the news feed positively affected their performance, progress, and motivation. In contrast, no correlations were found with the number of email notifications sent to students, although they seem to have positively affected student system use in general.

In summary, there is strong evidence for most motivational features positively affecting student self-motivation beliefs in the context of self-regulated learning, following the assumed relationships regarding student self-regulation in the forethought phase stated above. Email notifications do not seem to have a direct effect on student performance, progress, and motivation, but are one of the main triggers for student system activity. This goes in line with findings from prior research, for example Girgensohn and Lee [2002] and Farzan et al. [2008], who report that emails generally managed to increase the number of online sessions and page requests in web-based systems.

Time Management Time management is used for strategic planning as part of the task analysis in the forethought phase and self-control in the performance phase. While the former is concerned with goal setting and medium to long-term planning, the latter takes place recursively on a task and sub-task level while the learner follows the strategic plan. Good time management is associated with higher control over study time, reduced stress, higher self-confidence, higher quality output, and better student achievement (see section 2.3 on page 43). At the same time, time management is still considered to be an issue, especially in learning environments which focus on learner autonomy. Highly self-regulated learners are considered to be better in managing their time than less self-regulated learners.

In the monitoring system, time management was implemented as a set of tools for managing project-related tasks and events. Group events were also supported, but usually managed by monitors. In more detail, features concerned with time management were (i) the virtual project page outlining the project title, description, and associated users, (ii) a simple task list including due date, planned duration, start date, and colour-coded urgency flag, (iii) an event calendar on the project and monitoring group page, whereby group-related events were also listed in project calendars of their student members, and (iv) the virtual group page for group-related time management (mainly the organisation of group meetings).

Assuming that these features successfully affected student time management in the context of self-regulated learning, one would expect

1. Average student weekly progress ratings to be higher for students who used time management features often,

2. The student dissertation mark to be higher for highly active students.

Correlation analysis in section 6.2.1 on page 164 suggests that student use of features event calendar positively affected self and monitor-reported average student progress ratings. Student task use correlates positively with supervisor-rated average student progress ratings and their dissertation mark. Similarly, student use of the virtual project page positively affected the dissertation mark as well as self, monitor, and supervisor-rated average student progress. In contrast, use of the virtual group page only affected monitor and supervisor-rated average student progress. However, these results must be seen in the light of feature usage statistics presented in section 6.1.1: only 2.4% of all user interactions were made with tasks and 2.2% with the event calendar by 266 and 202 users, respectively. In the list of most used features, tasks are 10th and events 11th from the top. Usage of the virtual project and group pages was higher with 8.7% (335 users) and 6.3% (303 users) of user interactions, making these the third and seventh most used features, respectively.

The total number of tasks and events managed on the system was also analysed. On average, students managed 4.3 tasks in their project, 4 of which were pre-defined milestones added automatically before the start of the MSc projects. This means that only

0.3 tasks were managed using the task list on average, which is a very small number. The maximum number of student-managed tasks on the system at any given time during the 17-week period was 17. Likewise, event numbers were low with just under 1 student-managed event on average. This feature was mainly used by monitors (7.37 events on average) and supervisors (1.32 events on average).

In summary, there is inconclusive evidence in favour of time management features positively affecting student progress and performance. On one hand, positive correlations exist with student use of these features. On the other hand, usage statistics suggest that these features were not used frequently by a majority of students. Similarly, the number of student-managed tasks and events, that is, active use of these features was found to be low. At the same time, subjective feedback from the closing questionnaire suggests that users found both task list and event calendar helpful for MSc project management. Combining these findings with usage statistics, it can be hypothesised that the implementation of these features in the web-based system was unsuitable or too detached from other features and systems used in the school. For example, there was no direct link between tasks and the electronic hand-in system used in ECS, which was used by students to submit their project brief and the final dissertation. If this link had existed, submission of artefacts on that system would have led to the corresponding milestone task in the monitoring system to be marked as completed. This, in turn, would have led to more accurate task progress metrics visualisations.

Progress Awareness Awareness is when connected users in online systems or networks understand the activities of others, and when this understanding forms the context for their own activity (see section 2.4 on page 56). This is achieved by actively or passively capturing user activities and visualising them in suitable ways. This leads to an environment which is "infinitely rich in cues" [Schmidt, 2002] monitored and interpreted by other users. Prior research in the area of awareness reports positive effects on user connectedness in online collaboration spaces, user engagement as well as in-group communication in project-based group work on tasks, and user motivation [Dourish and Bly, 1992; Mochizuki et al., 2008; Hatziapostolou and Paraskakis, 2010]. In the context of this study, progress awareness refers to the capturing, visualisation, and user interpretation of MSc project progress information.

In self-regulated learning, progress awareness plays an important role in the performance and self-reflection phase. The former contains the self-observation aspect, which is when learners use metacognitive monitoring and record their progress and actions. In the self-reflection phase, this recorded progress information is used to evaluate their performance with regard to the learning tasks, make causal relationships between their actions and outcomes, and react adaptively or defensively to the outcome of the self-evaluation process. The established causality can positively or negatively affect student motivation. For example, students who applied good time management and strategic planning in the forethought phase are more likely to attribute their failure to bad planning. Conversely, students who did not apply strategic planning might attribute failure to low ability. Their reaction to failure, in turn, is dependent on their satisfaction. Highly satisfied students will adapt their approach to the task, whereas less satisfied students will react with procrastination, problem avoidance, or apathy because they think that their failure is down to internal or external causes they could not control. Progress awareness can also affect students' relative ability goal orientation and hence their self-motivation beliefs in the forethought phase, provided that they can monitor information about other students' progress on similar or the same tasks.

Against this background, progress awareness is a key catalyser of learner self-monitoring, self-evaluation, and self-motivation. As outlined above, these aspects are also dependent on time management strategies applied by students. In the context of this research study, the following features were implemented to support progress awareness:

1. Charts and graphs are displayed on the home, group, and project page. They visualise progress, motivation, and qualitative as well as quantitative report metrics submitted by students, their monitor, and their supervisor. The combination of these metrics is referred to as "project performance" in this work. These visualisations enable students to compare their project performance with that of other students in the cohort and monitoring group and analyse their progress over time. This directly affects their relative ability goal orientation and self-evaluation.

2. Similarly, a ranking table was provided underneath the chart panel on all three pages. The ranking is compiled using a score which is calculated based on progress and motivation indicators as well as the student's event attendance, determining the student's position/rank in the table. This allows students to quickly grasp their rank in comparison with other students in the cohort or group, affecting their relative ability goal orientation and self-evaluation.

3. The news feed goes beyond the visualisation of performance metrics since it lists all relevant actions of users with whom the student is associated. These are typically their monitor, their supervisor, and other students in the same monitoring group. Possible actions include (i) creation, modification, and cancellation of events, (ii) creation and modification of tasks, including when their percentage of completion is changed, (iii) comments and replies to comments on group pages, (iv) submissions of progress and event attendance feedback, and (v) modifications of general project data (title, description, etc.).

4. Email notifications for the purpose of raising progress awareness are (i) follow-up emails, sent when students did not attend a series of consecutive monitoring meetings and news feed emails, listing all news feed entries of the last 20 minutes. They are in place to ensure that information about online activity is pushed to all users whether they are currently online or offline.

To establish whether these features positively affected students' progress awareness, the collected data was analysed for correlations between student interactions with these features and the projected outcomes of progress awareness, namely motivation and performance. In theory, time management data could also be included in the analysis since it affects students' reaction to self-evaluated progress. However, only a few students made active use of these features in the system and 57% of closing questionnaire respondents indicated that they used other online or offline tools for time management and project planning. Data on the use of these external tools was not recorded.

Correlation analysis revealed that student use of charts and graphs positively affected their dissertation mark and self, monitor, and supervisor-rated weekly student motivation ratings. The correlation with self-rated motivation is slightly weaker than that with monitor and supervisor-rated motivation, indicating that the perceived motivational effect of these visualisations on students was slightly lower. More specifically, these results apply to the histograms showing the current and last week's distribution of student progress, motivation, and report quality ratings, and the trend graph plotting these metrics over time. Use of the event attendance and report metrics graphs also correlate positively and significantly with students' dissertation mark, but only use of the former graph seems to have positively affected student motivation ratings submitted by all user roles, while use of the latter graph only correlates with self and supervisor-rated motivation.

The analysis of ranking table use correlations was slightly more difficult since direct user interaction with this feature was not possible. Consequently, no direct usage data was collected. However, the table was displayed in a prominent place (just underneath the charts) on home, project, and group page, and usage data of these pages was used in correlation analysis instead. Although views of these pages does not exclusively correspond to ranking table views, it is likely that students were well aware of that feature when they viewed the page. Student usage of the home and project page positively affected students' dissertation mark as well as motivation ratings submitted by all user roles, whereas use of the group page only correlates positively with monitor and supervisor-rated student motivation. This can be explained by the group page being accessed fewer times compared to the first two pages: views of the home page make up 13.3%, those of the project page 8.7%, and those of the group page only 6.3% of all user interactions (see section 6.1.1 on page 151). Similarly, 343 users accessed the home page, 335 the project page, and 303 users the group page.

Student interactions with the news feed positively affected monitor and supervisor-rated student motivation. However, no correlation with students' dissertation mark was found. Likewise, email notifications received by students do not seem to have affected their motivation or performance. Therefore, an effect of these features on student progress awareness can be doubted. Although both features were rated helpful for project management by a majority of student respondents to the closing questionnaire, respondents were indifferent regarding their motivational effect. However, they agreed on the system raising their progress awareness and enabling them to compare themselves with their peers.

In summary, there is inconclusive evidence in favour of progress awareness features affecting student performance and motivation. While this was found to be likely for charts/-graphs and the ranking table, the news feed and email notifications are less likely to have had an effect. This was confirmed by subjective student feedback on these two features, whereas the overall system effect on students' progress awareness was rated positively.

Monitoring Monitoring is a cognitive process determining the current progress on tasks and goals and generating feedback which is the basis of further action [Butler and Winne, 1995]. Therefore, monitoring is always connected with feedback; section 2.5 on page 65 provided a detailed description of these two concepts. In self-regulated learning, monitoring happens in the performance and self-reflection phase. While working on learning tasks, self-regulated learners apply self-monitoring techniques, seek help from external sources, and apply task strategies. These actions require that they have defined goals in the forethought phase. Each goal has a profile containing the criteria for successful goal achievement, and goals are linked with a set of tasks whose completion leads towards goal achievement. In the monitoring process, learners assess the current task state, compare it with the criteria in the goal profile, and come up with so-called "discrepancy profiles" in the self-reflection phase, which are used to adapt goals, tactics, and strategies (self-reaction).

In the research study, monitoring was implemented in two ways. Firstly, a monitoring scheme was in place to enable group-based peer support and student-faculty contact on a weekly basis, in addition to traditional project supervision between the student and their supervisor. Secondly, the web-based monitoring system was provided to facilitate information exchange between roles and support the monitoring scheme in terms of planning, progress tracking, and most importantly feedback. More specifically, monitoring features provided were (i) student progress feedback, (ii) event attendance feedback, and (iii) in-group communication using group comments.

The analysis of collected usage data (see section 6.2.1) reveals that the submission of progress feedback positively affected students' dissertation mark, their overall project progress, and their motivation (rated by all user roles). The submission of event attendance feedback affected self, monitor, and supervisor-rated student progress and monitor-rated student motivation, while the dissertation mark was unaffected. Student use of group comments does not correlate with performance or average weekly ratings, given that only 47 users made use of this feature, accounting for only 0.1% of all system interactions. A detailed analysis of the number of group comments on the system reveals that this feature was mainly used by monitors to make group-wide announcements. Furthermore, subjective student feedback suggests that group comments were not perceived helpful and that more communication features are required to enhance user-to-user interaction.

In summary, there is evidence in favour of monitoring features positively affecting student performance, progress, and motivation. The primary aim of the system was to provide means for submitting weekly feedback as part of the monitoring process, while data on in-group communication in monitoring meetings was not collected and therefore not part of the analysis. In the monitoring system, feedback was mainly submitted as weekly progress reports. Usage of this feature correlates positively and significantly with student performance, progress, and motivation. In contrast, event attendance feedback was provided whenever meetings were managed on the system, but this was not consistently done in all monitoring groups and student projects. Consequently, usage data of this feature yields less robust results than that of progress reports. Similarly, group comments were used less frequently and are hence unlikely to affect student performance and ratings.

6.4.1.2 Hypothesis 2

The second hypothesis (5.2 on page 121) claimed that changes in student behaviour, measured using subjective student feedback, motivation ratings, progress ratings, and feature usage statistics, are indicators for the importance of corresponding features for project-based self-regulated learning and can therefore be used to extend and refine the list of suggested technologies supporting Chickering and Gamson's [1987] seven principles outlined in section 2.6 on page 66). In particular, Chickering and Ehrmann [1996] provide a list of technologies which they claim are suitable for implementing these principles, which is repeated here for convenience (see Table 6.29).

Table 6.29: Implementing the seven principles [Chickering and Ehrmann, 1996]

#	Principle	Suggested Technology
1	Student-faculty contact	Electronic mail, online conferencing, the Web
2	Student cooperation	Electronic mail
3	Active learning techniques	Tools supporting learning by doing, time-delayed exchange (forums), real-time conversation, word processing
4	Prompt feedback	Electronic mail, tools for recording/analysing personal performance
5	Emphasising time on task	Repositories (access to materials anywhere, any time), tools for recording participation and interaction, task management systems, asynchronous communication (electronic email)
6	High expectations	Tools demonstrating real-life situations, larger data sets, the Web as a platform for peer evaluation
7	Talents and learning styles	Tools supporting different ways of material presentation, adaptive systems, collaborative systems

This list is not very concrete and was compiled in 1996. Since then, new technologies and systems have been developed and used in the area of self-regulated learning, both in experimental and non-experimental settings. The aim of this work is to extend and refine these technologies based on empirical evidence gathered in this research study. It focusses on four out of the seven proposed principles since – as mentioned earlier – the remaining 3 principles were only implicitly supported by technology. The following paragraphs will discuss empirical results presented in section 6.2.2 and assess the suitability of each analysed feature for supporting the corresponding principle.

Encouraging Student-Faculty Contact According to Chickering and Gamson [1987], the primary aim of student-faculty contact is to encourage student involvement and enhance student motivation. Therefore, the suitability of each corresponding system feature is assessed using the following questions:

1. Was the feature used frequently enough compared to similar features?
2. Does student use of the feature correlate positively with student motivation?
3. Is the feature perceived motivational by students in the closing questionnaire?
4. Are there correlations between feature use, perceived motivational effect and helpfulness, and student motivation?

In the web-based monitoring system, features were in place to enhance student-faculty contact. In this context, two types of contact were introduced: active contact enables users to have interpersonal synchronous and asynchronous interactions with each other, while passive contact is when information is passed unidirectionally without direct interaction but based on such and with the intention to enable user connectedness and to provide a basis for forthcoming direct interaction (active contact). For example, in monitoring meetings, students and monitors discussed student progress. After each meeting, the monitor used the web-based monitoring to submit progress reports, event attendance feedback, and textual feedback on student progress. Students were notified by email whenever this happened and could respond by submitting their own progress reports, event attendance feedback, and textual feedback. In contrast, only one feature enabled active contact between users in a monitoring group, namely group comments. Email addresses of all users were also provided on the system, but email communication occurred externally and was therefore not logged. Passive contact features were (i) progress feedback, (ii) event feedback, (iii) visualisations (charts), (iv) the ranking table (displayed on home and virtual project page), and (v) email notifications.

The analysis regarding the effect of active contact features on student behaviour revealed that group comments were not used frequently by students but mainly by monitors for making announcements to the group. Consequently, no relationship was found with student motivation measured in weekly progress reports. Conversely, the majority of student respondents to the closing questionnaire found this feature motivating or very motivating, agreed on the helpfulness of monitoring meetings, and that their monitor/supervisor picked them up on progress reports submitted on the system. However, they did not find that the system helped them to communicate problems or contact other students. Similarly, they were undecided regarding the overall helpfulness of the system for keeping in contact with their monitor or supervisor during their absence. Interestingly, subjective student feedback regarding the helpfulness of the system for communicating problems correlates positively with the use of the group comments feature. It can be assumed that more frequent use of that feature would have led to better student-faculty contact and higher motivation. In their general feedback regarding the system, monitors also reported that communication mainly took place unidirectionally from monitor to student, and both monitors and students indicated that more advanced communication features would be required to overcome this problem.

In contrast, most passive contact features (charts, ranking table, home and project page, weekly progress reports, event attendance feedback) were used frequently by students and student usage of these features correlates positively and significantly with student motivation. Exceptions are student use of event feedback, which only positively affected monitor-rated student motivation, and the number of email notifications sent to students, which did not correlate with student motivation at all. A majority of student respondents also reported a high or very high perceived motivational effect of features charts, ranking table, progress reports of monitors and supervisors, event attendance feedback, and email notifications. It was also found that the number of progress report and event attendance feedback submissions positively affected students' perceived motivational effect of these features. Similarly, student use of charts correlates with the perceived motivational effect of the ranking table and progress feedback, and students who agreed with the system helping them to communicate problems submitted higher weekly progress ratings. The same applies to the perceived helpfulness of monitoring meetings, which also correlates positively with monitor-rated student progress and motivation. This is not surprising: student who did not find monitoring meetings helpful either did not attend these meetings or were probably less motivated and made less progress in the eyes of their monitor.

In Table 6.29, the following suitable technologies for implementing student-faculty contact are listed: email, online conferencing, and the Web. E-mail contact was not subject of this research, but certainly is a suitable technology and was probably used very frequently by students, monitors, and supervisors for that purpose, yet outside of system boundaries. Likewise, online conferencing is beyond the scope of this research. The Web, in contrast, is a very broad term referring to a whole range of technologies. Based on the analysis, this technology can be refined as follows:

- Online thread-based communication technology can enable active contact between student and faculty, provided that it is (i) available across organisational system units (project, group, etc.), (ii) intuitive to use, (iii) tied with other features enabling student-faculty contact, that is, not detached from them, and (iv) the preferred way of virtual interaction so that all system-related communication happens in one place. The group comment feature used in the web-based monitoring system is one example of such an implementation, but it was too detached from other contact features and hence not used frequently enough. Furthermore, it was slightly hidden away and therefore less intuitive to use. Students who did use the feature more frequently also agreed that the system helped them communicate problems.

- Technologies for online feedback generation are also suitable for encouraging student-faculty contact. In the web-based monitoring system, users were prompted to provide progress and event attendance feedback once a week, and the submission of this information correlates positively and significantly with student motivation, which is one of the purposes of student-faculty contact according to Chickering and Gamson [1987]. Furthermore, many students reported that their monitor and/or supervisor picked them up on such feedback in meetings. Progress reports and event attendance feedback were designed to be unidirectional from user to system, which then visualised the information back to the user. A direct dialogic interaction with these artefacts would be desirable, but was not implemented; this was the main critique of monitors. It is therefore suggested to combine active with passive contact features to enable more direct and context-related interaction between users.

- Visualisations of feedback data were also established to enhance student motivation and were perceived motivational by a majority of closing questionnaire respondents. Charts and graphs as well as the ranking table visualised progress information which was obtained during weekly meetings. Furthermore, as reported by students, they were often the basis for discussion in forthcoming meetings.

Emphasising Time on Task Effective learning is facilitated by time management, specifically focussing on time on task [Chickering and Gamson, 1987]. The monitoring system provided a set of tools for this purpose. Firstly, a task list was provided on the virtual project page, enabling students to manage and terminate tasks, plan the task duration, monitor the task urgency, and keep track of obligatory project milestones predefined before the start of the project. Secondly, an event calendar was provided on the group page, enabling monitors to manage weekly monitoring meetings, and on the project page for students to manage weekly meetings with their supervisor. Thirdly, the virtual project page itself, which allowed students to define their project subject, provide a small description, and see who their project monitor and supervisor is. This work will focus on the former two features in the context of this principle.

To determine whether the two features are suitable implementations of the principle, these four questions are to be asked:

1. Did students use the features?
2. Did students perceive them helpful for project management, in other words, did they serve the purpose they were designed for?
3. Does student use of the features correlate with their overall project progress (rated weekly by themselves, their monitor, and their supervisor) and student performance (dissertation mark)?
4. Are there correlations between subjective student feedback and these metrics?

Usage of both task list and event calendar by students was low: both features only account for 2.4% and 2.2% of all user-system interactions, respectively. Similarly, the total number of tasks and events actively managed on the system was low with students having 4.3 items on average in their task list (4 of which were predefined milestone tasks) and just under one event on average in their event calendar. Events were mainly used by monitors for the purpose of planning weekly monitoring meetings in their groups. The system also provided a data export feature, enabling students to export task data in CSV format and event data in iCalendar format, which was also used infrequently.

However, a majority of student respondents to the closing questionnaire indicated that they found both task list and event calendar helpful or very helpful for project management. Those who reported high event calendar helpfulness also submitted higher self-rated weekly progress ratings. Furthermore, student respondents reported that they used other external tools for time and project management, mainly Microsoft Project and paper-based tools. Contrasting this with usage statistics of the data export feature, it is questionable whether students used any of the system data in these external tools.

Student use of tasks positively affected their dissertation mark and supervisor-rated project progress. Self-rated overall progress remained unaffected, which indicates that students who used tasks more frequently than others did not report higher overall progress on their project. The use of events, in contrast, seems to have positively affected students' self-rated and monitor-rated project progress. However, these correlations must be seen in the light of usage statistics, which suggest that both features were not used very frequently.

Table 6.29 lists the following suitable implementations: repositories, participation and interaction recording tools, task management systems, and email. The results of the data analysis suggests that this list cannot be confidently extended or refined at this time. Both tasks and events were only used sporadically by a limited number of system users and correlations with student progress are therefore less meaningful. Taking this into consideration, there is some evidence for a positive effect of task use on student performance and progress rated by their monitor, and a positive effect of event use on student and monitor-rated student progress. Although self-rated progress remained unaffected by task use, a majority of student respondents to the closing questionnaire found them helpful or very helpful. Events were mainly used by monitors.

Surprisingly, there was not much subjective feedback from monitors regarding both task list and event calendar. Many students reported that they used other tools for task and project management. This might explain the low number of interactions with these features. Events were used more frequently, but there seemed to be some confusion over who was responsible for creating meeting events. Most monitors used the feature to manage weekly monitoring meetings; this was required as part of the monitoring scheme. The system also used email reminders which were sent to students who failed to create supervision meeting events in their project calendar. As mentioned earlier, supervisors were not required to use the monitoring system and hence did not create any events (with one or two exceptions).

Another weakness of the task list implementation was that it was relatively detached from other school systems, so that students had to enter data in several different places on some occasions. For example, the school provides an electronic submission system which was used by students to hand in their project brief and final dissertation. This could have been linked with certain milestone tasks in student projects, automatically marking these tasks complete after the student had submitted the corresponding artefact on the hand-in system.

Provision of Prompt Feedback Feedback is the result of monitoring and regarded as vital for effective student learning: "students need chances to reflect on what they have learned, what they still need to know, and how to assess themselves" [Chickering and Gamson, 1987]. This sentence accurately describes the cognitive processes behind monitoring, consisting of stock keeping (determining past performance), defining goals (future tasks), and self-assessment.

When evaluating the system's support for providing prompt feedback, the term "prompt" needs to be defined first. Chickering and Gamson [1987] do not provide an accurate definition for this term either but suggest that feedback should occur "timely" and while students perform learning tasks, that is, formative assessment alone is not sufficient. In the monitoring system, online feedback could be submitted once a week. Similarly, direct feedback in face-to-face interaction ideally took place twice a week in the weekly monitoring and supervision meeting. Monitors and supervisors then used the system to provide a summary of the impressions they got during meetings as weekly online feedback. This process can be regarded as relatively prompt since the MSc project takes 17-18 weeks on average and online feedback was provided once every week in the course of the project. However, since learning is an individual activity, different students will require feedback at different time intervals. In other words, students have different perceptions of the promptness of feedback and the question whether the system supported prompt feedback cannot be answered universally for all students. As in all educational processes, a compromise had to be found between "not enough feedback" and "too much feedback".

In order to evaluate the suitability of these features for the provision of prompt feedback, changes in student behaviour in response to the use of each feedback feature were analysed. Possible changes are in (i) student motivation, (ii) student progress, (iii) student performance, and (iv) subjective feedback in the closing questionnaire. In the web-based monitoring system, the following features were provided to enable weekly feedback:

1. A progress report, consisting of an overall progress rating, a motivation rating, and quantitative report metrics such as the number of words in the report body and the number of pages in the report appendix. A textual comment could also be submitted. Monitors and supervisors were also able to rate the quality of both report parts separately on a scale from 1 to 5. Alternatively, if monitors and/or supervisors had not seen their student in the corresponding week, they could indicate this in the submission. In the closing questionnaire, most student respondents found progress feedback from monitors and supervisors very helpful for managing their MSc project (supervisor feedback was perceived more helpful that that of monitors) and motivational. Submissions of progress feedback positively affected student performance as well as progress and motivation ratings by all three user roles.

2. An event attendance feedback for every past event in the student project or monitoring group calendar. This feedback was binary, that is, a meeting was either attended or not attended, and a majority of student respondents perceived this feature both motivational and helpful for project management. Submissions of event attendance feedback positively affected student progress ratings by all three user roles and monitor-rated student motivation.

3. Feedback was visualised and communicated in different ways:

    (a) Students received *email notifications* whenever their monitor or supervisor submitted feedback on the system. Likewise, monitors and supervisors were notified when the student submitted their feedback, enabling information exchange between the different user roles. Student respondents rated email notifications both helpful for MSc project management and motivational.

    (b) The above activities were also listed in the *news feed* of each associated user, which was rated helpful for project management by most student respondents. Correlation analysis also suggests that interactions with the news feed positively affected student progress, motivation, and performance. Furthermore, students who used this feature more frequently also found monitoring meetings helpful, reported that their monitor/supervisor picked them up on their progress reports, that the system helped communicate problems, keep contact with faculty staff, keep themselves organised, and enhanced overall MSc project management. Student news feed use also correlates positively and significantly with the perceived helpfulness of the event calendar, monitor and supervisor progress reports, the ranking table, and charts.

(c) Progress metrics were displayed in *visualisations* both anonymously (in charts and graphs) and directly (as a score in the ranking table) to enable progress awareness. Student chart use positively affected student performance, progress, and motivation, and students who used charts often also found supervisor progress reports more helpful. Similarly, use of the home page containing the ranking table positively affected student performance, progress, and motivation, and its usage correlates positively with students' perceived helpfulness of supervisor progress reports. The ranking table was also perceived helpful by a majority of student respondents.

(d) A *history of past progress reports* was listed on the virtual student project page, accessible by the student, their monitor, and their supervisor. Views of the project page positively affected student performance, progress, and motivation.

(e) Event attendance was displayed graphically in the list of participants of each past event in the calendar. Event usage positively affected self and monitor-rated student progress, but the feature was only used sporadically by students, so that a strong effect is unlikely.

Another important question is whether feedback was received timely by students after being submitted by monitors and/or supervisors. Figure 6.2.2 on page 179 in section 6.2.2.3 plots the number of student system logins against the number of progress reports submitted by monitors and supervisors for each day in the 17-week project period. It shows that student response to progress report submissions was relatively prompt: spikes in student logins are in line with spikes in progress report submissions. Students were notified of monitor and supervisor activity by email and on the news feed, and direct links to the system were provided in all emails. This is also partly confirmed by further analysis, which has shown that monitor progress report submissions correlate positively and significantly with student system logins, and that student progress report submissions correlate positively with monitor and supervisor logins, whereas supervisor progress reports are not significantly correlated with student system logins.

Against this background, Table 6.29 can be refined and extended as follows:

- Electronic email cannot only be used to convey feedback to students, but also to notify students of online feedback submissions. Although no concrete effects of email notifications on student progress were found, they were one of the main system use triggers, raising students' awareness of online user activity and changes. Therefore, they decreased the time used by students to respond to online feedback submitted by their monitor/supervisor.

- The monitoring system implements tools for recording and analysing personal performance: (i) weekly progress reports from students, monitors, and supervisors, and (ii) event attendance feedback, linked with events in an online calendar. There is strong evidence for both features positively affecting overall student project progress, in other words, students who submitted more progress reports also reported higher overall progress. This was confirmed by their monitor and supervisor. However, it seems that progress report submissions were more important than event attendance feedback since the former also positively affected student performance and motivation. The lower effect of event attendance feedback could also be explained by such feedback being dependent on the online management of events in projects and groups, which was not done consistently by all students and monitors. Strong and positive inter-correlations between weekly progress/motivation ratings by all three user roles and students' dissertation mark suggest that students' actual progress, motivation, and academic achievement were accurately reflected by progress reports. On the other hand, progress metrics acquired as part of weekly feedback were completely detached from the completion of tasks in the project task list, which is a possible explanation for infrequent student task use. The experimentation of new ways for assessing student progress in project-based contexts is subject to future work.

- The list must be extended by tools for displaying feedback activity and visualising progress metrics. The analysis has shown that a simple news feed, combined with email notifications, can greatly enhance student performance, progress, and motivation. It was also found that the overall helpfulness of the system for keeping contact, getting feedback on progress, and overall project management was rated higher by students who interacted with the news feed. Likewise, the use of charts such as performance histograms and trend graphs seems to have affected student performance. They raised students' awareness of their own performance in relation to the rest of the cohort and their self-evaluation abilities by providing visual means for the purpose of performance analysis.

Communication of High Expectations In order to motivate students at any achievement and efficacy level, Chickering and Gamson [1987] propose to "expect more and you will get more". They summarise this under the term "high expectations", denoting student encouragement to "make extra efforts" and to perform well. In the context of this research study, high expectations could be communicated in several ways:

Firstly, at ECS, a dissertation marking scheme is in place for all MSc programmes, outlining how the outcome of the MSc project (the dissertation) is assessed using a set of criteria such as scholarship, project management, technical soundness, etc. The marking scheme was available for download from the course website and was clearly advertised to all MSc students at the start and again towards the end of the project.

Secondly, weekly supervision and monitoring meetings were held to ensure that the project continues to meet high standards and leads to successful programme completion. This involves face-to-face and in-group discussions about technical particularities, academic writing, report structure, project management strategies, and similar skills. In monitoring meetings, students were also required to report on their project topic and progress in front of their peers. This was useful for acquiring feedback about discrepancies between expectations and current achievements from both the group and the monitor.

Thirdly, high expectations could also be communicated using the web-based monitoring system. In particular, supervisor and monitor ratings express the degree to which students meet high expectations regarding (i) their progress, (ii) their motivation, and (iii) the quantity and quality of their work. Furthermore, users were given the opportunity to provide textual feedback for the purpose of communicating expectations which were not explicitly covered by these ratings.

In the data analysis, the focus was on possible effects of weekly ratings and textual feedback on student motivation, which is the purpose of communicating high expectations, whereas the effect of face-to-face and in-group discussions could not be analysed since no objective data was collected during meetings. In section 6.2.2.4 on page 178, the results of correlation tests between the submission of progress and event attendance feedback by monitors/supervisors and student performance as well as motivation were presented. They show that supervisor feedback correlates positively with students' dissertation mark, in other words, the more feedback supervisors provided to students the higher their overall project performance. Furthermore, supervisor event attendance feedback had a positive effect on students' self-rated weekly motivation. In contrast, monitor feedback does not seem to have affected student performance or motivation. This can be explained by supervisor feedback being more highly valued by students due to the high degree of experience of supervisors and their overall authority with regard to both the MSc project and dissertation. Monitors did not have this authority and could merely provide additional support and facilitate in-group discussion and peer support. What is more, they did not have full insight into every student's project and their feedback was likely to be more general and hence less suitable for communicating high expectations.

To assess the true effect of faculty staff feedback on students, the content of textual feedback submitted as part of weekly progress reports was analysed. For this purpose, textual feedback was assigned to any combination of 8 content categories, namely (1) project status reports describing the student progress, (2) questions and answers, (3) positive remarks about student achievement, (4) negative remarks about unmet expectations, (5) general issues and problems preventing the student from making progress, (6) organisational remarks, (7) success stories, for example, reaching a project milestones or extraordinary student achievements, and (8) recommendations for improvement or problem solving. Comments could always be assigned to more than one category. In this analysis, the focus will be on categories 3, 4, 7, and 8 since they are most suitable for communicating high expectations. In particular, negative remarks often started with "I would have expected you to...". The other categories are of secondary importance here since they do not specifically communicate expectations.

It was found that positive remarks correlate significantly with student and supervisor-rated progress and motivation ($p < 0.05$). The highest effect was on self-rated student motivation ($r_s = 0.226$). Interestingly, no significant correlations were found between negative remarks and student-rated motivation or progress, while there are medium to strong negative correlations with supervisor and monitor ratings ($p < 0.01$). The latter finding is not surprising since both user roles would normally comment low ratings accordingly using negative statements. While positive comments seem to have motivated students, the communication of high expectations using negative comments did not have any effect on students' perceived motivation. Instead, these remarks might have led to increased effort on the part of the student, which would then result in positive comments in the following weeks. Finally, success stories correlate positively with self-rated student progress, whereas no significant correlations were found for monitor or supervisor recommendations in comments. Again, students who achieved extraordinary things in their project were unlikely to encounter problems and therefore made better progress on average.

In summary, there is evidence in favour of monitor and supervisor feedback being suitable for communicating high expectations in the context of the research study. It was found that supervisor feedback was more effective than that of monitors due to their higher authority and better insight into the project. Furthermore, positive remarks in textual feedback provided by monitors and supervisors positively affected perceived student motivation in the course of the project, while negative remarks did not have a significant effect. Chickering and Ehrmann [1996] propose the use of tools for demonstrating real-life situations, large data sets, and the Web for peer evaluation (see Table 6.29 on page 223). The web-based monitoring system used in the research study certainly falls into the latter category, although it was not intended for peer evaluation. Based on the discussion above, the list can be extended by web-based monitoring and feedback systems. More precisely, features which were particularly useful for communicating high expectations are: (i) progress ratings, (ii) event attendance feedback, (iii) textual comments submitted together with progress ratings, in particular positive remarks from monitors and supervisors. There is also evidence that the effect on student motivation could be further increased by making feedback more dialogic, that is, by enabling direct annotations or responses to feedback submissions, and by providing additional support for generating textual feedback to monitors and supervisors. This is because only 681 progress reports contained textual comments, compared to a total of 3887, 1429, and 599 progress reports submitted by students, monitors, and supervisors, respectively. A textual feedback generation tool might help to increase the proportion of progress reports containing textual comments, which have been shown to be much more useful than ratings alone.

6.4.1.3 Hypothesis 3

The third hypothesis is about monitor behaviour affecting student performance, progress, motivation, and system use, especially their system logins, views of progress visualisations, and activity on the virtual project page. Monitor behaviour includes their activity on the system, in particular submissions of weekly feedback.

The analysis of this hypothesis was presented in section 6.2.3 on page 182. It was found that student system activity correlates positively and significantly with that of monitors. In particular, student activity seems to be triggered mainly by monitor progress report submissions, their activity on the group page, and submissions of event attendance feedback. Conversely, monitor activity was mainly triggered by student activity on the group page, the event calendar, the project page, and their submissions of event attendance feedback. Also, user activity invariably triggered email notifications sent to associated users. The number of mails users received also correlates with their system activity. For example, student system logins correlate positively with event reminder emails, attendance feedback reminder emails, follow-up reminders (sent when students failed to attend a series of consecutive monitoring meetings), event news feed emails, event as well as progress feedback submission emails, and project task creation emails. Furthermore, student logins correlate negatively with progress feedback submission reminder emails (sent at the end of each week in case a student had not submitted their weekly feedback) and emails reminding students of tasks becoming due. This can be explained by less active students also being less likely to provide weekly feedback on time and keep their task list up-to-date.

What is more, correlations between the number of emails sent to students and their progress and motivation ratings suggest that students who received many event reminder emails also obtained higher motivation ratings from their monitor. These emails reminded students of upcoming monitoring meetings, provided that monitors managed their meetings using the web-based monitoring system. Those monitors rated student motivation higher, possibly because their students were more likely to attend meetings than those of monitors who failed to manage meetings online. Furthermore, students who received follow-up emails sent as a result of them not attending a series of meetings received lower progress and motivation ratings from their monitor. This is because non-attendance would result in monitors reporting a “not seen” feedback on the system. However, these mails do not seem to have negatively affected students’ self-rated motivation or progress. In contrast, progress feedback and task state reminder emails negatively affected self-rated student motivation and progress. It seems that those students were generally struggling with their project, although no correlation with supervisor and monitor ratings was found.

There are also time-related differences between user roles. For example, there is a markable downward trend in system activity over project weeks 2 to 16 with a peak in week 3 when system activity was maximal. System use is also significantly different between students, monitors, and supervisors with monitors using the system significantly more often (on average) than students and students more often than supervisors. This was already shown using descriptive statistics in section 6.1.1 on page 151. Furthermore, the fluctuations in user activity match between user roles, suggesting that there are time-related effects of the activities of one role on the others and vice versa. In contrast, student progress and motivation ratings are not significantly different between weeks and user roles, although progress ratings generally correlate with motivation ratings as shown earlier (see section 6.2.1.2 on page 169), that is, students who were motivated made better progress and vice versa. The analysis also reveals that average monitor ratings for both student progress and motivation dropped considerably after the first four weeks, reaching a minimum in the last four weeks. These results show that student system activity was influenced by that of monitors and supervisors and the opposite way round, while progress and motivation ratings of all three user roles remained relatively stable in the course of the MSc project and were not very different between roles. In more detail, student ratings were similar to those of monitors and supervisors, while monitor ratings were generally slightly (but not significantly) lower than those of the other two roles (see Figure 6.2.4 on page 187). This can be explained by monitors attending to a greater number of students with less insight into individual student projects and a lower expertise regarding the project topic.

There is also strong evidence that significant between-monitor effects exist regarding student system activity and performance. More specifically, students attended to by some monitors used the system significantly more often and received significantly higher dissertation marks, while there are no between-monitor effects regarding weekly progress and motivation ratings. On one occasion, positive monitor effects coincide, that is, students attended to by that monitor both used the system more often and received higher dissertation marks on average.

In order to assess whether there is evidence in favour of Hypothesis 5.3, related work on tutor effects on student behaviour must be considered. Prior research suggests that tutors can have positive effects on student achievement and attitudes towards the subject matter [Cohen et al., 1982]. In particular, Silver and Wilkerson [1991] found that the higher the tutor's subject expertise the more predominant their role in tutoring sessions, effectively reducing student-to-student interactions, which might have a negative effect on student self-directed learning. In contrast, Schmidt and Moust [1995] conclude that the tutor's subject expertise is as important in project-based learning environments as their communication skills and "empathic attitude" towards students. However, it was also found that tutors cannot compensate for a lack of student expertise in their subject area, suggesting that employing expert tutors is not sensible [Dolmans et al., 1996]. Analysing the effects of online tutors and their impact on e-learning quality, Sulčič and Sulčič [2007] report positive correlations between the average number of tutor comments with that of students in an online tutoring system. Finally, van den Boom et al. [2004] conducted a study involving reflection prompts on students' self-regulated learning processes combined with tutor feedback in a web-based learning system. Their study provides indications for this combination positively affecting students' self-regulated learning competence.

Although monitor expertise was not analysed as part of this research, monitors were mostly postgraduate research students from research groups in the school, and students were allocated to groups based on their project topic. Therefore, monitors were familiar with the topic area of their students and could provide adequate technical support and guidance. Monitors were also briefed to encourage in-group peer support and only intervene when students are unable to provide further support. This was to ensure that monitors did not take too predominant a role during meetings. Generally, the results of the analysis seem to support earlier findings about tutors positively affecting student performance. For example, there are significant between-monitor differences in students' average dissertation mark. It should be noted, however, that on some occasions students were allocated to groups based on their taught mark, which correlates strongly and positively with their dissertation mark. Furthermore, monitor system activity positively affected that of students and vice versa, indicating that there was a prompt bidirectional information exchange between both user roles. This was also enhanced by email notifications, but should be contrasted with subjective feedback from some monitors who found that information flow happened mostly unidirectional from monitor to student. Finally, it was found that monitor ratings on student motivation and progress were generally slightly yet not significantly lower than those of supervisors and students, which were very similar. This indicates that either supervisors aligned their feedback with that of students or the other way round, or that monitor feedback was less accurate with regard to students' "real" motivation and progress.

In summary, there is partial evidence in favour of the hypothesis. Monitor system activity led to markable positive effects on student system activity; email notifications were also beneficial. Furthermore, monitors had expertise in the topic area of the students in their monitoring group, but data about that expertise affecting student achievement was not recorded. The analysis has shown that students of some monitors performed significantly better than those of other monitors, which partially coincides with these students also using the system more frequently. It was also shown that the primary aim of the monitoring system, that is, enabling information exchange between monitors and students, was achieved.

6.4.2 Impact on Self-Regulated Learning

The previous sections provided a comprehensive discussion of all research results towards the main three hypotheses. The main purpose of this and the next section is to synthesise these findings and answer the following questions:

1. What system features were most effective in supporting self-regulated learning?
2. Based on these findings, how did the system affect student self-regulated learning?

While the first question is answered by ranking system features and their corresponding TSLAs based on statistical analysis results, the second question is approached by providing a narrative study with concrete examples using three sample students.

When it comes to deciding the overall effect of single system features on technology-supported learning aspects for students' self-regulated learning, the following metrics are taken into consideration: (i) effect sizes of correlations between student system use and their performance, motivation, and overall progress, (ii) usage statistics of features, (iii) perceived motivational effect, and (iv) perceived helpfulness for project management of features. A ranking was created to assess the contribution each of the system features made to their corresponding learning aspect(s). For this purpose, a simple score was developed, assigning an equal number of points to each of the four metric categories above as shown in Table 6.30.

Table 6.30: Score distribution of metric categories

Metric Category	i	Score γ	Description
Motivation Ratings	1	15	Maximum 5 points per user role j with $j \in [1, 3]$
Progress Ratings	2	15	
Dissertation Mark	3	15	
Perceived Motivational Effect	4	15	Maximum 5 points for each of the three highest Likert scale items j with $j \in [1, 3]$
Perceived Helpfulness for PM	5	15	

Each system feature is then rated in each metric category with regard to each of the four TSLAs, whereby features which were not designed to support the corresponding TSLA are excluded from the respective scoring algorithm. The score in relation to each TSLA ω_i with $i \in [1, 4]$ is calculated as listed in Table 6.31, where $r_s(c, x)$ denotes the coefficient (effect size) of the correlation between use of the corresponding feature c and variable $x \in \{m_i, p_i, a_d\}$ with $i \in [1, 3]$ denoting the user role (1 = student, 2 = monitor, 3 = supervisor), a_d the dissertation mark, m_i the average student motivation rating, and p_i the average student progress rating. Furthermore, $d(c)$ denotes the percentage of user interactions, $\beta_M(c, k)$ the percentage of student respondents who submitted a Likert scale rating of $k \in \{3, 4, 5\}$ on the perceived motivational effect, and $\beta_H(c, k)$ the percentage of respondents who submitted a Likert scale rating of $k \in \{3, 4, 5\}$ on the perceived helpfulness for project management of feature c. Feature use $d(c)$ is used as a factor in all scoring algorithms since it accurately expresses the relative impact the feature made on system users: less-used features made less impact and a lower contribution to the TSLA than more frequently used ones. Furthermore, each score is scaled by 100 to make it more readable. The total score ω per feature, which expresses the overall impact, is then simply made up as follows:

$$\omega = \omega_1 + \omega_2 + \omega_3 + \omega_4$$

Table 6.31: Score calculation per TSLA i

TSLA	i	Score Calculation
Motivation (M)	1	$\omega_1(c) = \left(\sum_{i=1}^{3} \frac{\gamma_1}{3} \cdot r_s(c, m_i) + \gamma_3 r_s(c, a_d) + \sum_{k=3}^{5} \frac{\gamma_4}{3} \cdot \beta_M(c, k) \right) \cdot d(c) \cdot 100$
Time Management (TM)	2	$\omega_2(c) = \left(\sum_{i=1}^{3} \frac{\gamma_2}{3} r_s(c, p_i) + \gamma_3 r_s(c, a_d) + \sum_{k=3}^{5} \frac{\gamma_5}{3} \beta_H(c, k) \right) \cdot d(c) \cdot 100$
Progress Awareness (PA)	3	$\omega_3(c) = \left(\sum_{i=1}^{3} \frac{\gamma_2}{3} r_s(c, m_i) + \gamma_3 r_s(c, a_d) + \sum_{k=3}^{5} \left(\frac{\gamma_4}{3} \beta_M(c, k) + \frac{\gamma_5}{3} \beta_H(c, k) \right) \right) \cdot d(c) \cdot 100$
Monitoring (MN)	4	$\omega_4(c) = \left(\sum_{i=1}^{3} \left(\frac{\gamma_1}{3} r_s(c, m_i) + \frac{\gamma_2}{3} r_s(c, p_i) \right) + \gamma_3 r_s(c, a_d) + \sum_{k=3}^{5} \left(\frac{\gamma_4}{3} \beta_M(c, k) + \frac{\gamma_5}{3} \beta_H(c, k) \right) \right) \cdot d(c) \cdot 100$

and $\tau(c)$ indicates the ordinal rank of feature c. The result of the scoring algorithms ω_i is shown in Table 6.32, whereby scores were rounded to enhance readability. Furthermore, the ordinal rank $\tau_i(c)$ is provided for each feature and its score with regard to the corresponding TSLA i, whereby excluded features were not ranked; the corresponding cell in Table 6.32 is therefore left blank. It should also be noted that the perceived motivational effect of features events and data export was not rated in the closing questionnaire and is hence not considered in the scoring algorithm. Furthermore, no ratings were obtained for the project, group, user profile, and home page. Thus, ratings for the ranking table, which was displayed on these pages in a prominent place, are used when calculating scores for the project, group, and home page; no ratings are used for the user profile page. What is more, email notifications have to be excluded from scoring since there is no accurate way of measuring user interactions with this feature. Their importance for raising user awareness outside of system boundaries is out of question.

The results in Table 6.32 show that current week's performance histogram chart (histogram 1), the home page including the ranking table, and the project page were the most influential and therefore essential features for self-regulated learning. In contrast, group comments, task and milestone statistic charts, and the data export were the least influential features.

Taking a closer look at the top five high-ranking features of each TSLA (also listed in Table 6.33) and assessing their importance for self-regulated learning, the following

Table 6.32: Scores ω_i and ranks τ_i of system features relative to technology-supported learning aspects

Feature	M (ω_1)	τ_1	TM (ω_2)	τ_2	PA (ω_3)	τ_3	MN (ω_4)	τ_4	ω	τ
Event			14	8			14	14	28	13
Data Export			5	11			7	15	12	15
Group & Ranking	36	7	37	6	58	6	73	6	204	6
Home & Ranking	142	2			188	2	238	2	568	2
News Feed					12	10	15	12	27	14
Group Comments							1	18	1	18
Project & Ranking	87	3	89	2	117	3	146	3	439	3
Tasks			18	7			30	9	48	11
Profile	40	6					65	8	105	8
Progress Feedback	49	5	49	4	68	5	86	5	252	5
Event Feedback	28	8	42	5			69	7	139	7
Histogram 1	260	1	262	1	348	1	437	1	1307	1
Histogram 2	67	4	68	3	89	4	115	4	339	4
Performance Graph	12	10	12	9	16	8	20	10	60	10
Attendance Graph	13	9	11	10	18	7	20	11	62	9
Report Chart	10	11			13	9	15	13	38	12
Milestones Chart	1	12	1	12	2	11	2	16	6	16
Task Chart	1	13	1	13	2	12	2	17	6	17

results are obtained:

Motivation The learner's self-motivation beliefs are developed in the forethought phase based on their self-efficacy, their outcome expectancies, their interest in the learning task, and their goal orientation. Most effective features in this learning aspect are (1) current week's performance histogram chart, (2) the home page including the ranking table, (3) the project page including the ranking table, (4) last week's performance histogram chart, and (5) progress feedback. The histogram charts directly visualise the result of the learner's action regarding their learning tasks and therefore influence their outcome expectancies: students who received high progress ratings are more likely to feel more motivated as they become aware of their achievements. Furthermore, the charts depict the learner's own performance in comparison with that of the cohort, which is made up by students studying on the same programme, hence working on similar projects. This influences the learner's goal orientation, especially if they apply a relative ability goal orientation: the learner becomes aware of other learners' abilities and progress and will be motivated to work harder on their tasks if they feel that they are falling behind. Another way of visualising student progress is the ranking table, which was displayed on the home, project, and group page. It turns out to be another essential feature for motivation, especially because it directly ranks users against each other, providing

Table 6.33: Top 5 features for each technology-supported learning aspect

Aspect	Rank	Feature	Score
Motivation	1	Histogram 1	260
	2	Home & Ranking	142
	3	Project & Ranking	87
	4	Histogram 2	67
	5	Progress Feedback	49
Time Management	1	Histogram 1	262
	2	Project & Ranking	89
	3	Histogram 2	68
	4	Progress Feedback	49
	5	Event Feedback	42
Progress Awareness	1	Histogram 1	348
	2	Home & Ranking	188
	3	Project & Ranking	117
	4	Histogram 2	89
	5	Progress Feedback	68
Monitoring	1	Histogram 1	437
	2	Home & Ranking	238
	3	Project & Ranking	146
	4	Histogram 2	115
	5	Progress Feedback	86

more concrete information than histograms. Finally, the action of providing progress feedback itself is also important. The learner reflects on their own progress and receives external feedback from their monitor and supervisor, enabling them to assess if their perception is in line with that of other (competent) people who are familiar with their tasks. This can directly affect the learner's self-efficacy. For example, if positive feedback was provided by their supervisor, they might feel more confident in themselves as a result.

Time Management Time management skills are required in the forethought phase for strategic planning (goal setting) and in the performance phase for continuous planning of concrete tasks. The results in Table 6.32 show that essential features for time management were (1) current week's performance histogram, (2) the project page including the ranking table, (3) last week's performance histogram, (4) progress feedback, and (5) event attendance feedback. Again, charts seem to have supported students in planning their work; the histograms depicted student progress relative to the cohort, enabling students to get a feeling for their overall progress in comparison with their peers. This facilitates the process of detecting one's own progress (self-monitoring), in reaction to which one can adjust the plan (self-reaction). Similarly, progress feedback enabled the learner to record their observation about their own progress, and they were also provided with observations from external sources (monitor, supervisor), allowing them to assess whether both observations match or if adjustments are necessary. Event attendance feedback was in place to track students' attendance of monitoring and supervision meetings. If they chose not to attend those meetings, they would risk obtaining a "not seen" rating from their monitor/supervisor, which might have made them attend meetings more often and stick to the project schedule.

Progress Awareness Progress awareness is when students are aware of their own and their peers' project process. In self-regulated learning, this supports them in the self-reflection phase, when they assess their progress and decide on appropriate reactions with regard to the project plan. Therefore, it refers to internal processes which are difficult to measure. Features which were found to be most effective are (1) current week's performance histogram, (2) the home page including the ranking table, (3) the project page, (4) last week's performance histogram, and (5) progress feedback. The histogram charts were specifically designed for raising progress awareness since they show the distribution of progress ratings over the cohort and a marker denoting the student's position in that histogram. In other words, students could assess whether they are weak, average, or strong compared to their peers. Another more direct way of achieving this was to provide a ranking table on the home page, which also contained the news feed visualising the activities of associated users. Although direct interactions with the news feed were much lower, it can be assumed that users took notice of it and were aware of other users' activities. Progress visualisations (charts, ranking table) were created based on data originating from weekly progress feedback, which was the fifth-highest ranked feature and displayed together with other project-related data on the project page, another high-ranking feature. In self-regulated learning, these tools directly support the learner in self-observation and self-monitoring, and they also influence their relative ability goal orientation: if a students finds that their performance is much lower than the average in their cohort, they will be more motivated to work harder.

Monitoring In this context, monitoring is a cognitive process in which a person evaluates progress relative to a set of goals and gives feedback which can be used to make an informed decision on further action [Butler and Winne, 1995]. Goals are set in the forethought phase as part of the strategic planning process, while monitoring usually takes place in the performance phase when learners actively work on learning tasks and apply self-observation strategies. In so doing, they assess the current state of each task and compare it to so-called goal profiles, which contain a set of criteria for goal achievement. The resulting discrepancy profiles are then used to change strategies or adapt goals. The top five system features which were found to support monitoring are the same as those for progress awareness. This is not surprising since progress awareness is part of the monitoring process. Charts enable students to assess task states and compare them with their own and externally defined goals (intended learning outcomes). This can be done relative to the project – students consider progress feedback of their monitors and supervisors – or relative to other learners who do similar projects. The latter can be achieved by consulting the ranking table displayed on the home and project page.

In summary, system features were ranked regarding their impact on technology-supported learning aspects for self-regulated learning. It was shown that there is considerable overlap between features supporting progress awareness and those for monitoring, which can be explained by these aspects being similar in the way they affect student self-regulation. Charts, progress feedback, the ranking table, and the virtual project as well as home page are considered particularly important for self-regulated learning. However, the scoring algorithms chosen are only one way of interpreting statistical results, and more data is needed to generate more accurate feature rankings.

6.4.3 Student Narratives

Now that the possible impact of system features has been assessed, a concrete narrative case study is provided to further explore the underlying processes which might have led to the correlations found in the data from a student perspective.

Narrative case studies are part of qualitative research and describe/interpret a particular phenomenon from the perspective of a person [Flyvbjerg, 2011]. A technique called narrative inquiry is used to create these studies, assuming that humans "make sense of random experiences by the imposition of story structures" [Bell, 2002]. The resulting narratives are not entirely produced by the author but rather based on "social, cultural, and historical conventions" [Pavlenko, 2002] and the relationship between author and audience. A prominent example of this kind of study is that of Biggs [1999], who introduces two sample students, namely "academic" Susan and "non-academic" Robert, to explore how students can be engaged in learning activities which make them apply "higher order learning processes".

For the purpose of the narrative case study presented here, three students are introduced. They are not concrete subjects from the data set but purely virtual, although it is possible that there are students in the cohort resembling these example students.

Student A is a very bright student. In the taught part of his MSc programme, he got a total mark of 86%. His studies are characterised by a high degree of autonomy, he often reads around the subject in all modules he has chosen. The taught part was slightly challenging, but due to his strategic planning and good time management, he managed to finish all his assignments well on time and started his exam revisions early enough. Needless to say that he attended most of his lectures in order not to miss cues from teachers and ask questions about the material. He seems to have a good feeling for his own abilities and knows himself well enough to make accurate predictions regarding effort and time to put in. He is also very interactive, plays an active part in all in-class discussions, and is a good team member in all groupwork assignments. His tutor he meets once a month and although he never encounters serious problems he attempts to make it to every single meeting. Other students would describe him as 100% reliable: all tasks assigned to him are always performed with utmost precision and completed by the deadline.

Student B one would describe as an average student. On her taught MSc modules, she obtained a total mark of 65%. She generally goes with the flow and mostly studies just what is required from her to obtain an average or slightly above average mark. Although she has some strategic goals, she often fails to see how to achieve them and is generally insecure regarding her own abilities. Consequently, she struggles with time management, sometimes misses lectures, meetings with her tutor, and group meetings. Assignments she hands in about half a day or a day late on average because she underestimates the time required to complete them and hence starts too late. Her peers regard her as partially reliable, but tasks assigned to her she always masters with a medium to high-quality output. In group-discussions she usually takes a back seat and only makes contributions when addressed directly.

In contrast, student C is always on the edge. He just about passed his taught part. He also struggles with the English language and both reading and writing are a challenge to him. For his bad academic performance he often blames others. His goals are mostly outside of his study life, he has little interest in his learning tasks, and generally does not spend a great deal of time studying. His learning style is characterised by experimentation, whereby he tries to get away with as little effort as possible. This sometimes involves taking advantage of other students, especially in group assignments. Meetings with his tutor or peers he partly forgets, partly ignores because he regards them as a waste of time. He hands in assignments about 3 days late on average, and his exam revision is selective in the sense that he only revises key materials and does not have a deep understanding of the subject area. In group or in-class discussions, he avoids direct contributions and involvement. If he cannot avoid them, the quality of his output is usually poor. Other students regard him as utterly unreliable.

Using these three students, a possible scenario of using the web-based monitoring system in the context of self-regulated project-based learning is provided, taking the results of the research study into consideration. All students undergo the 17-week MSc summer project commencing in June and ending at the end of September.

Student A is a highly self-regulated learner. He shows a high degree of self-initiative and perseverance on his learning tasks, has a high self-efficacy, and shows deep interest in the task itself and the learning material. He is therefore driven by learning goal orientation, that is, he is fully focussed on learning the material, while the relative performance of his peers in the same course is of minor importance to him. One can hence assume that his motivation is fairly high from the outset. In his project brief, he provides a clear outline of all project tasks including due dates and planned duration. This outline is the result of strategic planning, and his goal is to achieve the highest possible mark and get a distinction on his project. He comes forward with his own ideas regarding possible solutions to existing problems, attends all monitoring meetings, and actively participates in group discussions. Since he has a broad knowledge of his subject area, he is also able to provide help and advice to other students. As a result, both his monitor and supervisor are pleased with his progress and submit high motivation and progress ratings throughout. He also uses the system frequently to provide feedback on his progress – merely for self-recording – and accesses the system to read the comments of his monitor and supervisor in response to email notifications he receives. In the beginning, he tries to cheat by providing the highest possible rating on both his progress and motivation in order to get to the top of the ranking, but he soon realises that his monitor's and supervisor's ratings are also taken into account. Generally, however, his own ratings are in line with those of his monitor and supervisor as he is very aware of his own abilities and uses system features and meetings for self-observation purposes. In the ranking table for his course he is always amongst the top 5 students, which reassures him that the self-assessment of his self-efficacy is accurate and that desired outcomes can be achieved, increasing his self-motivation beliefs. He also uses the graphs and charts available, but mainly for tracking his progress over time and to confirm that he continues to deliver high quality output. The motivational effect of these visualisations is relatively low because the project itself is the source of his motivation – he simply does not need to compare himself to other students. On his virtual project page, he keeps the list of existing project tasks up-to-date and completes most of his milestone tasks well ahead of time, although he mainly uses external tools such as Microsoft Project, Google Calendar, and paper-based methods for project management purposes and therefore does not keep many tasks in the online task list. Furthermore, he manages meetings with his supervisor and provides prompt feedback on attendance. Whenever he encounters a problem, he uses the feedback of staff (provided on the system or in face-to-face interaction) for self-evaluation purposes. As he is generally satisfied with his progress, the outcome of this process combined with external feedback is used to (i) adapt the plan, for example, by changing priorities of tasks, (ii) change his approach to the tasks by applying a different technique or seeking alternative solutions, and (iii) update his expectations regarding the task outcome. Visualisations of online feedback support him in this process: monitors and supervisors provide textual recommendations with their weekly feedback, and graphs indicate that he still performs better than the average, for example, in the first weeks after commencement of the project when a majority of students are struggling because they have to make themselves familiar with the technical and theoretical particularities of their topic. In monitoring meetings, student A is always in the position to describe his problem precisely, based on the outcome of his self-evaluation, feedback on the system, and his strategic plan.

Student B, on the other hand, is less self-regulated. She contributes relatively little to the actual project, which she got assigned by her supervisor as she had not come forward with her own ideas. Consequently, her interest in the subject is only average, and she constantly needs to be challenged explicitly by her monitor and supervisor in order to persevere. She is also unsure of her own abilities and often feels that tasks are out of her depth. The project plan she comes up with is relatively vague and her goals are not clearly defined. She completes her practical work more or less on schedule, while the writing up process is a bit of a struggle to her. One can assume that her self-motivation beliefs are about average and that the degree of effort she puts into the project is very much influenced by external factors. Her use of the web-based monitoring system is sporadic and she merely reacts to email notifications and reminders. She provides feedback on her own progress and manages supervision meetings in her online project calendar; her meeting attendance is about 80%. Feedback she receives from monitors and supervisors is mostly positive and/or contains textual advice on how to improve and overcome problems; this motivates her considerably. Her virtual task list on the project page she does not use actively, although she manages to update her progress on milestone tasks. Due to her low to medium self-efficacy, her self-observation and progress monitoring is very much focussed on staff feedback and her progress relative to that of her peers. The latter she finds visualised in charts and the ranking table. Most of the time, her ratings are in line with the cohort's average, and in the ranking table she is in the upper middle. However, she recognises the names of other students in his monitoring group who are doing better than her, and she pays particular attention to their contributions in meetings and on the virtual group page. Using the performance of these students as a benchmark, charts and the ranking table enhance her effort and motivation since she has a relative ability goal orientation. When she encounters a problem, her reaction is very much dependent on the feedback of others, but she successfully adapts her strategy or approach to the tasks, and is mostly satisfied with her actions. However, student B often struggles to describe her problems directly due to below-average self-recording.

Finally, student C is poorly self-regulated. At the start of his MSc project, he had a topic assigned to him by his supervisor. His interest in the topic is very low, he does not plan strategically, and he does not believe that he can successfully master the tasks his supervisor has set. One can therefore assume that his outcome expectancy, self-efficacy, and hence also his self-motivation beliefs are low. His use of the monitoring system is very sporadic and mostly passive: he barely provides feedback on his progress feedback and receives average to low ratings from his monitor and supervisor. Most of the time, he only becomes active on the system in response to email notifications. On his virtual project page, the task list is updated infrequently and progress on milestone tasks is not recorded. Similarly, no external tools are used for time and project management, so that self-observation of progress is severely affected. Furthermore, he does not manage supervision meetings in his project calendar, and his total meeting attendance rate is about 70%. Monitoring meetings he attends only in the beginning, attendance then drops in the middle of the project period and is zero by the end of it. Consequently, monitor feedback does mostly consist of "not seen" ratings. In response to that, the system sends out frequent email reminders to encourage the student to attend meetings and keep their online tasks up-to-date. Self-rated motivation and progress seem to increase slightly in response to supervisor and monitor feedback, but overall satisfaction remains low throughout. Also, he views charts and graphs as well as the ranking table frequently, but his low performance compared to his peers in combination with staff feedback sometimes lead to defensive reactions, that is, the student attributes his failure to external factors he deems impossible to control. Some of his problems he blames on failing equipment or lack of support from external sources, which results in problem avoidance and procrastination. His monitor detects that he is struggling, but there is little they can do other than reporting back to the C's supervisor (using the monitoring system) because C stopped attending monitoring meetings. His inactivity on the system also leads to an increased number of reminder email notifications. Although feedback and progress visualisations on the system generally have a positive effect on his motivation, his lack of interest in the topic and poor strategic planning as well as time management are difficult to compensate. When writing up towards his final report, the literature review is a particular challenge due to problems with the English language, and little is written up in the early or middle stages of the project. Consequently, he starts to panic when the final dissertation deadline is looming.

6.4.4 Supporting Student Project Management

Project management refers to skills required for successful project-based learning [Thomas, 2000], but without taking collaborative aspects into account – the MSc project is an individual project not normally containing any group work component. In particular, students are required to work autonomously on a set of given tasks and are responsible for problem investigation, decision making, project planning, and producing suitable solutions to the problem. Successful application of these skills is crucial as students are only given a relatively small period of time (3 months) to investigate the problem, do their practical work and produce a solution, and finally describe the approach in their dissertation.

The monitoring system provided a set of tools for this purpose. Firstly, students could plan their tasks by indicating a due date, a planned duration, a percentage of completion, and inter-dependencies with other tasks. Secondly, a simple project calendar was provided, enabling students to put down meetings with supervisors and monitors, and any other events they wanted to keep track of. Email reminders were sent out before each meeting and whenever tasks became due or overdue. Thirdly, all data could be exported and used with other external applications such as Microsoft Project. Fourthly, students themselves, their monitor, and supervisor submitted weekly feedback on the student's overall project progress using the system. This data was aggregated and presented visually on graphs/charts and in a ranking table, enabling students to compare themselves with their peers on the same course.

As with motivation, it is hard to judge whether student project management has improved as a result of system use. Project management is one of the criteria in the dissertation marking scheme, so the dissertation mark could be used as one indicator of good project management. However, this measure is not exclusive to project management. Unfortunately, the detailed contribution of each marking scheme criterion to the final mark was not disclosed to the researcher and could therefore not be used in the analysis. Another approach is to ask users whether they agreed with several general statements representing good project management practices, and also let them rate a list of features with regard to their helpfulness. Then, overall progress ratings submitted by students, monitors and supervisors could also be used as an indicator for good project management, arguing that those students who managed their project well also made better progress on average. Finally, dissertation submission statistics could be used to evaluate whether students showing high system use were more likely to meet their dissertation hand-in deadline. All four approaches to this problem were undertaken.

Positive correlations were found between system use and average overall student progress ratings as well as helpfulness ratings of certain system features in the closing questionnaire. These are the ranking table, progress feedback submitted by supervisors, and event attendance feedback. Usage of features event calendar, home page, project page, and several charts and graphs visualising progress metrics also correlate positively and significantly with student progress ratings. However, there are no correlations with any of the five main statements for good project management, that is, students using the system more frequently did not necessarily find that the system (1) helped them to keep themselves organised, (2) enabled the communication of problems, (3) helped them to keep contact with their monitor/supervisor, (4) facilitated contact with other students on their course, and (5) enhanced overall MSc project management. However, the majority of students indicate agreement with the last statement. Moreover, weekly student progress ratings correlate positively with both taught and dissertation mark, although correlations with the dissertation mark have higher effect sizes (see Table 6.21 on page 198) – except for monitor-rated student progress and motivation. This means that students who did well on their taught part on average also achieved higher progress ratings, in other words, they could have been good project managers from the outset and the system might not have had any effect on their project management skills.

Moreover, a comparison of the number of days students submitted their dissertation late with previous years 2008 and 2009 was conducted, assuming that good project management can be measured by their ability to meet the final submission deadline. The results suggest that the number of days actually increased in 2010. Furthermore, a related-samples comparison with in-course deliverable submissions of a Research Methods module coursework and the MSc project brief yielded the same result. This means that students' overall ability to meet deadlines has decreased significantly.

In summary, although there are relationships between helpfulness ratings of certain system features and system use, these might be purely random and are therefore weak indicators for a markable student project management improvement. Furthermore, overall student progress ratings are only an indirect measure of good project management and the number of late penalty days in 2010 increased considerably compared to previous years 2008 and 2009.

Chapter 7

Conclusions and Future Work

The work presented in this thesis focuses on technology support for self-regulated learning in a project-based context in higher education. For this purpose, the model of self-regulated learning proposed by Zimmerman [2011] was chosen since it is a more recent one and synthesises the latest findings in this area. Self-regulated learning is a cyclic and iterative process consisting of three distinct phases, namely forethought, performance, and self-reflection phase. In the forethought phase, the student analyses the learning task, sets goals, and performs strategic planning towards these goals. Other key aspects in this phase are student self-efficacy, outcome expectancy, interest in the task, and orientation towards goals. In the performance phase, the student then performs learning tasks applying various self-control mechanisms such as time management, environmental structuring, and help seeking, while they also observe their progress applying monitoring and recording techniques. The outcome of the performance phase is used for self-evaluation and self-reaction purposes in the self-reflection phase, where students take stock of their achievements and change their task approach and learning behaviour in the next iteration of the cycle.

When it comes to computer support for this process, four key aspects were identified, namely (i) student motivation, (ii) time management, (iii) progress awareness, and (iv) monitoring. This work refers to these aspects as *technology-supported learning aspects* (TSLAs).

Motivation is a key driver for learning and influences the learner's effort and persistence on the learning task as well as their achievement [Zimmerman, 2011]. It can originate from high learner beliefs in their own abilities, their interest in the learning material or task, their expectancies regarding the task outcome, and their orientation towards goals. The latter aspect denotes the way they approach, engage in, and respond to achievement situations [Pintrich and De Groot, 1990]. While some students focus on learning the material, others try to show their ability relative to other learners. Positive links were found between learners' self-motivation beliefs and their academic performance [Pintrich and De Groot, 1990]. Prior research in this area has mainly focused on intelligent tutoring systems [del Soldato, 1994; del Soldato and du Boulay, 1995; de Vincente, 2003], online virtual characters [Kim et al., 2006; Rebolledo-Mendez et al., 2006], and theoretical models [Keller, 1987; Keller and Burkman, 1993]. Motivated learners were also found to be better in planning their work than unmotivated students [Francis-Smythe and Robertson, 1999].

Time management is important for strategic planning and also a self-control mechanism in the performance phase, and consists of three processes, namely goal management, planning, and scheduling [Zimmerman et al., 1994]. While it is still a problem encountered by many students [Main, 1980], prior research has found positive links between good time management and academic achievement [Macan, 1990; Britton and Tesser, 1991]. Furthermore, its importance for project-based learning, where the focus is on learner autonomy and self-regulation, was emphasised by Thomas [2000]. There have been several approaches aimed at supporting university student time management using special software tools, especially using mobile technology in the context of lifelong learning [Sharples, 2000; Holme and Sharples, 2002; Corlett et al., 2004], or standard software tools [Blandford and Green, 2001].

Progress awareness, that is, the learner's understanding of other learners' progress on learning tasks in the same or similar virtual context, is used to encourage students, enhance their connectedness, and increase the amount of information used to develop relative goal orientation [Dourish and Bellotti, 1992; Mochizuki et al., 2008; Markopoulos, 2009]. This is achieved by capturing user interactions, visualising them in suitable ways, and interpretation of such information by the learner in the self-reflection process [Brézillon et al., 2004]. Furthermore, raising student progress awareness can assist their self-observation in the performance phase of self-regulated learning. Since some of other students' performance information is also disclosed, relative goal orientation and hence self-motivation is also affected.

Monitoring is the process of generating feedback, which is important for the learner's self-reflection on their achievement and current progress. Such feedback can originate from the learner themselves or external sources such as faculty staff. For this process to be effective, accurate data on intended task outcomes should exist. This is the case when the learner has applied strategic planning and task analysis in the forethought phase [Butler and Winne, 1995]. Feedback is also supposed to be prompt [Chickering and Gamson, 1987] and dialogic, which can be supported by software tools [Carless et al., 2011]. While prior research has looked at the effect of feedback on student engagement, no concrete studies on the support of learner self-regulation, motivation, and achievement have been conducted so far.

Against this background, the aim of this thesis has been to examine ways of using computer technology for enhancing self-regulated student learning and thereby also implementing four out of seven principles for good practice in undergraduate education proposed by Chickering and Gamson [1987], with the primary focus being on the four

TSLAs introduced earlier. The relationship between these concepts and the TSLAs is depicted in Figure 6.4.1 on page 212. More specifically, Chickering and Gamson [1987] propose to (i) encourage student-faculty contact for the purpose of instigating student motivation, (ii) to give prompt feedback to students, (iii) to emphasise time on task in order to encourage good time management, and (iv) to communicate high expectations to challenge students at any achievement level to make extra efforts. For this purpose, two research studies were conducted using online systems in the School of Electronics and Computer Science (ECS) at the University of Southampton. The set of features for these systems was chosen based on ideas from related work regarding the four TSLAs and on the results of a time management technology survey in the school. The latter has shown that students use a wide range of computing and mobile devices, and an individual combination of calendaring tools for time management, supporting and extending findings in related work [Blandford and Green, 2001]. A more detailed presentation of these results can be found in Chapter 3. Consequently, all systems were designed web-based so that they could be used across devices and platforms, and contained integrated time management, progress tracking, and awareness features. More specifically, simple planning tools such as task lists and calendars were implemented. In a study conducted by Sharples et al. [2005], participants indicated that such tools had the greatest impact on their personal organisation. Student task progress data was used in various visualisations aimed at raising their progress awareness [Dourish and Bellotti, 1992], that is, students could compare themselves to their peers by understanding the activity of others on related tasks or projects, setting the context for their own activity. Mochizuki et al. [2008] used a similar mechanism and reported that this encouraged students in project-based settings to work on their own tasks. This was combined with user's social online presence, which is also believed to influence student motivation [Bai, 2003]. Furthermore, students should be encouraged to adopt good time management practices. Britton and Tesser [1991] and Macan [1990] have shown that this can positively affect their grade point average.

An initial study was conducted which informed the design of a successful second study. Proactive features were added to create the new system, it was more closely integrated into existing systems, and embedded into an educational strategy (the monitoring scheme). In this second quasi-experimental study [Field and Hole, 2006], the new web-based information system for monitoring Master of Science (MSc) projects was used by 378 participants in the school in 2010, 290 of which were students (see Chapter 5 for details). The study was not truly experimental since it was a school requirement that all MSc students should have the opportunity to use the system, hence the sample could not be divided into a treatment and a control group. During student enrolment with the university, students consented to their data being stored for performance analysis purposes.

The design of the information system was enhanced by a complementary monitoring scheme offered in addition to traditional MSc project supervision, aimed at progress tracking, encouraging professional project planning, and peer support. Following this scheme, every MSc student attended a weekly meeting run by a monitor, who was required to give feedback on student progress using the monitoring system. Supervisors and students were not formally required to use the system, but students were given a short system presentation before the official start of their summer project and were encouraged to use it for planning their project.

The aim of all research presented here was the analysis of three main hypotheses, which were introduced in section 5.3 on page 119 and are repeated here for convenience:

1. The use of software features supporting TSLAs positively affects students' self-regulated learning, whereby features designed for motivation and progress awareness positively affect student motivation and transitively student performance, time management features positively affect student progress and transitively their performance, and monitoring features positively affect student progress, motivation, and performance.

2. The use of TSLA features leads to measurable changes in student behaviour, mainly (i) perceived helpfulness of features, (ii) perceived motivational effect, (iii) weekly motivation ratings, (iv) weekly progress ratings, (v) academic performance, (vi) feature usage, and (vii) any correlations between aforementioned measures. These changes demonstrate the suitability of corresponding features for project-based self-regulated learning and lead to extensions and/or refinements of technologies proposed by Chickering and Ehrmann [1996] implementing four out of seven principles introduced by Chickering and Gamson [1987]. In particular, changes associated with progress feedback, event attendance feedback, and group interactions support the "enhance student-faculty contact" principle, those associated with time management features support the "emphasising time on task" principle, and those associated with progress awareness and monitoring features support the "prompt feedback" and "communication of high expectations" principle.

3. Feedback and activity of monitors positively affect student motivation, performance, and system use in the context of monitoring MSc projects, showing that the educational strategy is effective in combination with software and that it enables a feedback cycle between monitors and students.

The following paragraphs will list any evidence for each of these hypotheses, any inconclusive findings, and any uncertainty about findings relating to them. This summarises the main contributions of all research presented here, which are:

1. Based on the model of self-regulated learning presented by Zimmerman [2011], four central aspects are identified and supported by technology: motivation, time management, progress awareness, and monitoring. Motivation is the key driver of learning and dependent on the learner's self-efficacy, outcome expectancy, goal

orientation, and interest in the learning task. Time management is important for strategic planning and scheduling of tasks and sub-tasks. Progress awareness enables the learner to reflect on their own progress in relation to that of other learners and facilitates their self-evaluation. Finally, monitoring generates feedback, which is also used for self-evaluation purposes. For each of these aspects, a set of supporting software features was designed and integrated into an online MSc project monitoring system, which was combined with a complementary monitoring scheme (educational strategy). In the course of a 17-week quasi-experimental study, objective and subjective data was collected and analysed. The analysis reveals that features supporting motivation (progress and motivation feedback, progress visualisations, and the news feed) are positively and significantly related with weekly student progress and motivation ratings as well as their dissertation mark. Furthermore, there are positive statistically significant relationships of progress awareness features (progress charts, ranking table), time management features (task list, event calendar), and monitoring features (progress feedback) with student motivation, progress and performance. The impact of these features can be explained by the underlying processes of student self-regulation. What is more, section 6.4.2 on page 236 provides a impact ranking of features for each TSLA and a narrative case study exemplifying system impact on the self-regulation of three sample students.

2. The data collected in the research study was also used to make informed extensions and/or refinements of technologies for implementing four of seven principles for good practice in undergraduate education [Chickering and Ehrmann, 1996], which are directly related to the four TSLAs mentioned earlier. In particular, statistical analysis reveals that *student-faculty contact* can be encouraged using thread-based virtual interactions which are intuitive to use and tightly integrated with other contact features. Furthermore, the principle can be implemented using online feedback tools and visualisations of feedback information using charts, graphs, and ranking tables. *Prompt feedback* can be provided using email notifications in combination with progress feedback tools, but also by suitable visualisations of feedback data such as performance charts and graphs. Finally, *high expectations* can be communicated using web-based monitoring and feedback systems, in particular if they contain features enabling regular submissions of progress ratings and event attendance reports in combination with textual feedback. The list of technologies supporting the *emphasis of time on task* cannot be extended or refined confidently at this time since system features supporting this principle were not used frequently enough.

3. The web-based monitoring system was provided in combination with a monitoring scheme, whereby students were assigned a monitor whose responsibilities were to provide technical support and guidance, enable peer support in group meetings, and communicate problems to academic supervisors. It was shown that the system supported this scheme: monitor system activity is positively and significantly

related with that of students, there were significant between-monitor effects on student performance and system use, and there is evidence that the system enabled information exchange between monitors and students.

7.1 Technology Support for Self-Regulated Learning

Self-regulated learning is a central aspect of today's education environments, which increasingly emphasise learner independence and learner-centredness. It is particularly important in project-based learning contexts, where students are posed with a central problem or question they have to investigate, understand, and internalise [Thomas, 2000]. Self-regulation in these contexts requires the learner to be proactive, persistent, and show personal initiative as their learning is no longer controlled by teaching [Zimmerman, 2002]. Zimmerman [2011] provides a more recent process model of self-regulated learning (see section 2.1 on page 24), which is when students are active participants in the learning process in terms of their metacognition (the thinking about one's own mental processes), motivation, and behaviour. In the model, there are three distinct phases which happen iteratively and recursively, namely the forethought, performance, and self-reflection phase.

This work has identified four central aspects which can be supported using computer technology and which are referred to as *technology-supported learning aspects* (TSLA) throughout this thesis. They were chosen based on prior research in this area.

Motivation Motivation was chosen because it is one of the key drivers of self-regulated learning in the forethought phase. A great deal of prior work is available on motivation in the context of intelligent tutoring systems, particularly the detection of the learner's current motivational state and the adaptation of learning material as well as tutoring style to that state [del Soldato, 1994; del Soldato and du Boulay, 1995; de Vincente, 2003]. These systems are less suitable for self-regulated learning since they are based on the idea of instruction, and unsuitable for project-based settings since they are too specific. More recent work in project-based learning was done by Mochizuki et al. [2008], who found that disclosing task progress information in group work projects to all team members encouraged them to work on their own tasks, made them feel more connected, and increased their "sense of a learning community". In contrast, the research presented in this work is set in individual project-based setting, where collaboration plays a minor or no role at all. In self-regulated learning, motivation is dependent on the learner's belief in their own capabilities to master the learning task, their interest in it (the task value), their outcome expectancies, and their goal orientation [Zimmerman, 2011]. A learner's goal can either be the internalisation of the learning material itself or a particular achievement in relation to other students in the same cohort [Pintrich and De Groot, 1990; Wolters et al., 1996]. It is assumed that the more motivated a learner is, the better their time management and overall progress, which in turn leads to better overall achievement and learner satisfaction.

In the web-based monitoring system, motivation was implemented using the following features: (i) weekly progress and motivation feedback, (ii) graphical visualisations of progress data (charts and graphs), (iii) a ranking table on the virtual home, project, and group page, and (iv) email notifications. Weekly motivation feedback was rated on a Likert scale by students themselves (self-perceived motivation), their monitors, and supervisors. A 5-point scale was chosen because users are familiar with it and motivation was one of 4 metrics which were rated. Therefore, the implementation of a comprehensive questionnaire based on motivation models (see section 2.2 on page 26 for examples) was infeasible as its completion would have been too time-consuming. A correlation analysis showed that average weekly motivation ratings from different user roles strongly and significantly correlate. Furthermore, motivation ratings correlate positively and significantly with the students' dissertation mark, indicating that these ratings can accurately predict student performance and that perceived student motivation was not significantly different between user roles. However, a one-dimensional motivation rating might not be robust enough to make implications regarding different types and aspects of motivation (see motivational models in section 2.2.4.1 on page 35). Future work might want to look at other ways of assessing and recording student motivation as part of weekly feedback in project-based settings.

In this thesis, it was shown that there is strong evidence in favour of motivation features positively affecting student motivation, progress, and performance. In more detail, there is a positive and statistically significant relationship between ranking table views (displayed on the home, project, and group page) and average student weekly motivation and progress, and their dissertation mark. The ranking table shows the rank of the currently logged on student in relation to the course or group and also shows the names (and links to their profiles) of other students. This seems to have affected students' relative goal orientation in the sense that their aim was to obtain a higher ranking than their peers. In cases where positive feedback is submitted by monitors and students, students' self-efficacy is also affected. Progress feedback from students directly supports their self-recording and metacognitive monitoring (student-rated progress and motivation). Furthermore, their self-evaluation and self-judgement is also influenced by monitor and supervisor feedback, which is constantly compared to students' perception of their own progress, motivation, and report quality. Furthermore, graphical visualisations of student performance data, in particular performance histograms and the performance trend graph, are likely to have positively influenced students' relative goal orientation, self-efficacy, and outcome expectancies. For example, high ratings might have led to students feeling more confident about their ability to achieve set goals. This transitively affected their overall progress on the project and hence their dissertation mark. Finally, the news feed was also found to be positively related with student motivation, progress, and performance. It displays the activity of other associated users on the system; this was complemented by email notifications pushing this information to the user's email inbox. For example, when a monitor submitted feedback on a student, this activity showed up on the student's news feed and resulted in an email notification being sent to the student. This process also enhanced the student's self-observation and supported their self-evaluation in the self-reflection phase. These results are also reflected in the impact ranking presented in Table 6.33 on page 240, which lists the two performance histograms, the home page, the project page, and progress feedback as top 5 features for the motivation aspect.

In the narrative study presented in section 6.4.3 on page 242, possible effects of these features were outlined. Student A (the good student) is less likely to be driven by relative ability goal orientation since he is very interested, tends to read around the subject, and focuses on learning the material and investigating a problem. Progress feedback and visualisations thereof are therefore merely used to confirm that he is on track and provide reassurance regarding outcome expectancies and the effectiveness of the strategic plan. They also aid him in monitoring his progress while working on learning tasks in the performance phase. Similarly, student A is assumed to be satisfied with his strategy and progress and is more likely to attribute problems or lack of progress to the plan rather than his own ability. This means that he will adapt the plan or approach to tasks based on negative progress feedback, while less self-regulated learners (student C) tend to apply an avoidance strategy, leading to procrastination and further problems. The average student (student B) is less secure regarding her personal abilities, has done some strategic planning and time management, but also has less confidence in her goals being achievable. Consequently, B is more susceptible to external feedback and tends to take it more seriously than student A. She applies a relative ability goal orientation, tries to perform well in relation to particular people in her monitoring group or on her course, and hence pays more attention to progress visualisations. Textual feedback provided by monitors and supervisors has a greater impact on her self-judgement, and her reaction to such feedback is dependent on her current satisfaction, self-efficacy, and outcome expectancies. Student B also generally requires more attention from staff than student A. Finally, student C will attribute failure on learning tasks to external factors and react in a defensive way. His use of the online monitoring system is less frequent, and he fails to participate in monitoring meetings. His motivation regarding goals and learning tasks is generally poor and unlikely to be affected by other people's feedback. Graphical progress visualisations and the ranking table are less likely to affect his overall motivation since his interest in the task is low.

Time Management Time management is another central aspect of self-regulated learning, since it influences the learner's task analysis and strategic planning in the forethought phase and also their ability to follow and adapt the plan in the performance phase. While good time management has been linked with better grades, more control over time, and less stress, it is still one of the main issues encountered by most students.

Substantial prior research is available on time management in mobile learning [Sharples, 2000; Sharples et al., 2005] and the application of existing standard software [Blandford and Green, 2001].

Earlier in this thesis, the effect analysis of time management features on student progress and performance was presented. Positive and statistically significant relationships were found between the use of (i) events and student as well as monitor-rated student progress, (ii) tasks and supervisor-rated student progress, and (iii) the virtual project page and student progress as well as their dissertation mark. Although student respondents to the closing questionnaire perceived the former two features (events and tasks) helpful for project management, their usage of these features remained low throughout the study and very few students managed their project tasks online. Events were mainly used by monitors to manage monitoring meetings. At the same time, many students indicated that they used other external tools, mainly Microsoft Project, paper-based methods, and Google Calendar, for this purpose. The data export feature was also hardly used by students, so that it is questionable whether event or task data was used directly outside system boundaries. There are two possible reasons for low usage of time management features. Firstly, the task list was too detached from other systems used in the school. For example, students had to submit their project brief and final dissertation to an electronic hand-in system. Had this system been linked with the monitoring system, a submission would have triggered the completion of a project milestone task in the task list. However, since this was not the case, students had to mark these tasks as complete manually. Secondly, there was no direct way to import tasks and events from external tools into the online system, which might have deterred students who preferred other tools to share their data online. These issues should be investigated further and are therefore subject to future work.

Nevertheless, the feature impact ranking in section 6.4.2 on page 236 suggests that there are secondary features supporting student time management. In particular, graphical progress visualisations enable students to get a feeling for their own progress compared to that of other students in the same course or monitoring group, influencing their self-evaluation in the self-reflection phase. Progress feedback from monitors and supervisors contributed to self-observation and self-control in the performance phase, facilitating the adaptation of both student strategies and their approach to learning tasks. Similarly, the project page listed all project-related data including graphs, events, tasks, and past progress feedback on a single page, enabling students to observe and evaluate their own progress.

Regarding the narrative case study, students A and B are likely to use events for managing meetings with their supervisor and update their progress on milestone tasks, but little can be said about their hypothetical use of these features had they been more intuitive to use and/or better implemented. Also, student A does not really need any project management support; he is fairly organised since he has a strategic plan and a set of scheduled tasks in place, and he possibly uses other tools to manage them.

However, he also makes use of visualisations of progress feedback for monitoring and self-observation purposes, and includes this information in his self-evaluation process. This process involves (i) observing the current progress state of his tasks, (ii) comparing it to the expected progress, and (iii) attributing a cause to any discrepancies occurring. This will lead to an appropriate adaptive self-reaction, for example, changing the plan, adapting the approach to tasks, and overcoming problems preventing him from making progress. Student B will also adapt her plan as a result of self-observation, however, as it is less accurate and extensive, the evaluation of her own progress will be less accurate and her self-reaction might also be less appropriate. Furthermore, external feedback has a much greater impact on her self-evaluation. In contrast, student C is unlikely to make any particular effort to keep his data up-to-date, either because of language barriers or lack of interest. He does not have a strategic plan and is therefore unable to timely detect lack of progress or difficulties. Once he becomes (or is made) aware of problems or failures, he will attribute them to external factors and react with avoidance and procrastination, which will eventually lead to further problems. In these cases, the system features progress feedback and progress visualisations are meant to be helpful for monitors and supervisors since they (i) enable information exchange between user roles, (ii) visualise problems, and (iii) enable rapid difficulty detection. Although the analysis of system usefulness for this type of scenario was not the main focus of this research study, subjective monitor feedback suggests that the system facilitated student progress tracking, monitoring during monitor or student absence, and enhanced overall MSc project monitoring (see section 6.1.5.2 on page 162). In contrast, monitors were divided over its helpfulness for problem detection and communication to students and/or supervisors.

Progress Awareness In this work, progress awareness is used to create an environment which is "infinitely rich in cues" [Schmidt, 2002] denoting own and other students' progress data in a shared context. The context is made up by a course (programme of study) or a monitoring group, ensuring that students work in the same topic area and that projects have a fairly similar structure within that topic area. Therefore, from a student perspective, progress information available in that context is equally "relevant" to all users and can be used as a benchmark for their own progress. In technical terms, progress awareness refers to (i) active or passive information capturing on the system, (ii) visualisation of that information, and (iii) information interpretation by the user [Brézillon et al., 2004]. With the advent of Web 2.0 technologies, the use of progress awareness techniques in e-learning systems has also increased, creating systems that "appeal" to users [Sclater, 2008], enable direct participation and interaction, and support the idea of "social learning" [Ebner et al., 2007]. Many features known from successful Web 2.0 applications such as news feeds and other user interaction visualisations directly contribute to progress awareness. When it comes to self-regulated learning, progress awareness is a catalyser of self-monitoring, self-evaluation, and the development of self-motivation beliefs. In more detail, the disclosure of progress data enables students to observe their progress on learning tasks and evaluate their performance based on observed progress and feedback from external sources, leading to changes in their motivation.

The web-based monitoring system used (i) graphical progress visualisations (performance histogram charts and performance trend graphs), (ii) a ranking table on the home, project and group page, (iii) a news feed, and (iv) email notifications to implement progress awareness. To establish whether the use of these features had any impact on student self-regulation, statistical analysis was applied to find relationships between usage data and students' motivation as well as their performance (the dissertation mark). Positive and statistically significant links were found between (i) student use of charts/graphs and average weekly motivation ratings from all user roles as well as their dissertation mark, (ii) student views of the home and virtual project page and student motivation ratings as well as performance, and (iii) student interactions with the news feed and monitor as well as supervisor-rated student motivation. Interactions with the group page were lower than those with the project and home page, and it also contained less student progress information, so that it also contributed less to students' progress awareness. No positive and significant relationships were found with the number of email notifications received by students, although they were generally one of the main system use triggers. The correlations do not necessarily match students' subjective feedback on the helpfulness of charts for progress awareness: the majority of respondents were undecided regarding performance histograms and the performance trend graph. However, a majority also found that the system enhanced their overall progress awareness.

Quantifying the impact of features on student progress awareness, performance histograms, performance trend graphs, and the ranking table had the highest effect on student motivation ratings and dissertation mark, while student interactions with the news feed only led to monitors and supervisors reporting higher student motivation on average. The former three features support students' self-observation and monitoring in the performance phase since they visualise their ratings relative to the cohort (histograms) and also over time (performance trend graph). Histograms and the ranking table also directly affect the self-motivation belief of students with relative ability goal orientation since they enable the direct comparison with other students in the same course or monitoring group. In the self-evaluation process, the student then combines their self-observed progress with ratings submitted by their monitor and supervisor (these are displayed on the virtual project page), leading to a reaction on the part of the student. This self-reaction can be adaptive or defensive based on the degree of student self-regulation. For example, student A in the narrative case study described in section 6.4.3 on page 242 is highly self-regulated, has a strategic plan, is highly satisfied, and will therefore apply adaptive measures, for example, by changing the strategic plan, his approach to a task, or by overcoming difficulties preventing him from making progress. Student B's reaction is very much dependent on feedback from her monitor/supervisor: positive and constructive feedback suggesting possible ways to overcome a problem is likely to sustain or enhance her satisfaction and self-motivation. In contrast, student C will probably react defensively (avoidance, procrastination) due to a non-existing strategic plan, low outcome expectancy, and insufficient goal orientation. Therefore, visualisations are also less helpful to student C for self-observation purposes in the performance phase as this requires an existing project plan and goal profiles.

Monitoring Besides being the primary focus of the web-based monitoring system, monitoring can be regarded from two perspectives. Firstly, from a self-regulated learning perspective, monitoring refers to the learner's self-observation strategies in the performance phase. One of them is metacognitive monitoring, which refers to the learner monitoring the thinking about their own mental processes. The second is self-recording, whereby learners record their progress on learning tasks. Secondly, from an external perspective and in project-based settings, monitoring is the process by which faculty staff observe and record student progress on their project. This information can be used to (i) identify students who struggle, (ii) detect problems in student projects, and (iii) exchange progress data with other members of faculty staff. Recorded progress can be communicated back to students in the form of feedback, which can greatly enhance student self-judgement in the self-reflection phase. Consequently, the student has two different types of feedback available: internal feedback (their own perception of their progress) and external feedback (that of monitors/supervisors). The effect of monitoring on student self-regulation is dependent on different factors. Firstly, the student should have made a strategic plan with a set of goals in the forethought phase. This includes a set of goal profiles, containing concrete criteria for goal completion. Secondly, during the performance and self-reflection phase, more data becomes available on task states and student progress. Both the goal profiles and current task states are then compared as part of the monitoring process, creating so-called discrepancy profiles, which are used by students to adapt their tactics and strategies in the next iteration of the self-regulated learning cycle [Butler and Winne, 1995].

In the research study, monitoring was supported in two ways. A monitoring scheme was in place to provide group-based peer support and to monitor student progress. In addition, the web-based monitoring system was used to record student progress, to enable information exchange between user roles, and to support the monitoring scheme by providing features for event management and feedback submission. In particular, monitoring features provided are (i) progress feedback, (ii) event attendance feedback, (iv) progress visualisations, and (v) in-group communication using group comments. Effective monitoring features are hypothesised to enhance student self-observation and self-evaluation, leading to higher student motivation, progress, and ultimately their dissertation mark.

It has been shown that progress feedback submissions are positively and significantly related with student average weekly progress and motivation, and with the student dissertation mark, while event attendance feedback submissions only affected average weekly student progress and monitor-rated student motivation. The analysis of the impact of features on technology-supported aspects of self-regulated learning has also revealed that the histogram showing current week's student performance against the cohort as well as the virtual project page were important monitoring features. The histogram supports student self-observation while also providing information about their progress in relation to other students. Furthermore, the project page contained a detailed list of past feedback submitted by users in association with the student project. In contrast, group comments do not seem to have had a considerable effect on student progress, motivation, and achievement. This was due to the fact that it was not used frequently by both students and staff. One possible explanation is that this feature was only provided in the context of the monitoring group and not in any other context (project, system-wide). It is therefore suggested that this feature is extended so that it can be used in any system context and that users are encouraged to use it over other means of communication to make it more effective. Whether this improves the effectiveness is subject to future work.

When it comes to the narrative case study, student A is a very organised student, using system features appropriately for self-recording and self-evaluation. He provides weekly feedback on his progress and motivation, and also textual comments with every feedback containing further information about the state of his work to his monitor and supervisor. He also uses graphical progress visualisations to verify that he is on track. In addition to his own records, he checks the system regularly (and when prompted by email notifications) for monitor and supervisor feedback, which – combined with what he takes away from regular meetings – help him to evaluate his progress on the project. In particular, he analyses any discrepancies between his own and monitor/supervisor feedback and comments, which helps him to attribute a cause to problems or any lack of progress. As a result, he can make an informed decision as to an adaptation of his learning approach. Student B, the insecure student, is not very self-efficacious and can quickly doubt her ability to reach a set goal or complete a learning task. Her self-motivation beliefs are more dependent on external factors, therefore monitors and supervisor feedback have a higher impact on her self-evaluation and self-reaction. Although she uses the system less frequently, she pays great attention to monitor and supervisor feedback, and she also uses visualisations to inform her decisions. In contrast, student C is indifferent regarding learning goals and tasks, and online self-recording happens sporadically if at all. Consequently, feedback from his monitor or supervisor is unlikely to have a deep effect.

7.2 Technology Support for the Seven Principles

Similarly, Chickering and Gamson [1987] proposed seven principles for good practice in undergraduate education with the aim of providing guidelines for addressing the problem of "pathetic", "illiterate" students and "incompetent", "impersonal" teaching environments. Unsurprisingly, a subset of these guidelines are directly or indirectly supported by features in the web-based monitoring system. For example, Chickering and Gamson [1987] propose the encouragement of student-faculty contact in order to increase student involvement and motivation, which corresponds to the set of features designed for the enhancement of motivation. Other principles correspond to one or more elements of technology-supported learning aspects, or are not explicitly implemented as technology but part of the monitoring scheme. A detailed overview of all principles and their corresponding features and monitoring scheme elements are listed in Table 7.1. In the table, an asterisk is used to mark features for which strong and conclusive evidence gathered during data analysis suggests that they support the corresponding principle. It should also be noted that the development of student cooperation, the use of active learning techniques, and respect for diversity were not directly supported by technology. Furthermore, MSc projects are by default individual projects not containing any group-work, therefore cooperation beyond peer support and group discussion during monitoring meetings was not explicitly supported by either the web-based system or the educational strategy.

Table 7.1: Seven principles of Chickering and Gamson [1987] and supporting technology or educational strategy aspects; asterisks denote that strong and conclusive evidence exists for a feature supporting a principle

#	Principle	Aim	Supporting Feature(s)	Supporting Strategy Aspect(s)
1	Encouraging student-faculty contact	Enhance student involvement and motivation	Progress feedback*, event feedback, visualisations*, group page, group comments, email notifications	Monitoring meetings, supervision meetings
2	Developing student cooperation	Increase student understanding	(Group comments, group page, news feed)	(Meetings)
3	Using active learning techniques	Making learning an activity	–	Practical work, monitoring meetings
4	Prompt Feedback	Encourage self-reflection	Progress feedback*, email notifications*, project page*	Meetings
5	Emphasising time on task	Foster effective time management	Task list, event calendar, project page*, group page	Meetings
6	Communicating high expectations	Encourage students to make extra efforts	Progress feedback*, event feedback*, visualisations*, ranking table*, news feed, email notifications*	Direct feedback and discussions in meetings
7	Respect diversity	Allow students to learn their own way	–	Meetings

In later research, Chickering and Ehrmann [1996] provide a list of technologies (see Table 6.29 on page 223) suitable for implementing these guidelines, and also emphasise the need for an educational strategy into which all technology should be embedded to be effective.

Based on the results of the statistical analysis performed on data collected in the research study and subjective student feedback, an extended and refined list of technologies was compiled and presented earlier (see section 6.4.1.2 on page 223), focussing on principles 1, 4, 5, and 6, that is, principles which are directly supported in the web-based monitoring system.

Encouraging Student-Faculty Contact Principle 1 suggests to encourage student-faculty contact with the aim of increasing student involvement and motivation. Chickering and Ehrmann [1996] propose that email contact and the Web are suitable ways of implementing this guideline. Since email contact went on outside the boundaries of the web-based monitoring system, no data was collected about its frequency and efficiency in terms of supporting the principle. The second technology, the Web, refers to a great variety of applications and tools. Statistical analysis of feature usage, its correlation with student motivation rankings, and their perceived motivational effect have led to a number of extensions and refinements, providing a more detailed outline of web features suitable for supporting this principle. Firstly, the use of thread-based user comments on the group page does not directly correlate with student motivation ratings and was used infrequently, while it was perceived motivating or very motivating by the majority of student respondents to the closing questionnaire. Furthermore, students agreed that monitoring meetings were helpful and that monitors used feedback submitted on the system in group discussions. At the same time, the perceived helpfulness of the system for communicating problems or contacting other students was low. As mentioned earlier, this can be explained by group comments being too detached from other system features, so that they were mainly used by monitors to make group announcements. Had they been available in more contexts and more intuitive to use, one would probably obtain a different result. This assumption is supported by general subjective feedback: both monitors and students indicated that more advanced communication tools are required to overcome this issue. It is therefore suggested that thread-based online communication technology can be used to implement principle 1, provided that it is available beyond the group context, more intuitive to use, and used as the main communication channel.

Secondly, users were prompted to submit weekly feedback on student project progress and attendance of monitoring and supervision meetings, subject to them being managed on the system. This was not done consistently, but a decent number of interactions were made with these features. Submission of progress feedback is positively related with student motivation ratings, which either indicates that students who submitted and received feedback were more motivated or that those who were more motivated also submitted and received more feedback. In combination with subjective feedback, which suggests that a majority of respondents were picked up on their online feedback by monitors/supervisors, it can be assumed that technologies for online feedback submission encourage and enhance student-faculty contact. As suggested by monitors in their general feedback in the closing questionnaire, a more dialogic nature of this process is desirable and subject to future work.

Thirdly, visualisations of progress metrics (graphically or by using ranking scores) can also contribute to enhanced student-faculty contact, since this information was subject of discussions in meetings; a majority of student respondents indicated this. Their use correlates positively and significantly with average weekly student motivation ratings.

Emphasising Time on Task Principle 4 is about putting time on task first in order to make students learn effective time management. The system supports time and project management by providing (i) a project page, (ii) a project task list with four pre-defined tasks representing important project milestones, and (iii) an event calendar for managing supervision meetings. The data was analysed regarding the use of these features, their perceived helpfulness for project management, and any correlations with average weekly student progress ratings. Chickering and Ehrmann [1996] suggest the use of repositories, participation and interaction recording tools, task management systems, and electronic mail for implementing this principle, whereby the web-based monitoring system certainly falls in the task management system category.

It was shown earlier that both task list and event calendar were only used infrequently, although a majority of student respondents perceived them helpful for project management. Positive and significant correlations exist between student use of the task list and their dissertation mark as well as supervisor-rated average weekly progress, student use of the event calendar and self as well as monitor-rated project progress, and student use of the project page with their dissertation mark as well as weekly progress ratings from all three user roles. In contrast, no correlations with the taught student mark were found. As mentioned earlier, low feature usage numbers can be explained by a lack of deep integration with other school system such as the electronic submission system, which was used by students to hand in their project brief and final MSc dissertation, so that students had to manually update their progress on milestone tasks. Furthermore, no data import facility was provided, discouraging those students who indicated that they used external tools for time and project management from sharing such data online. This would have greatly enhanced transparency and enabled monitors as well as supervisors a deeper insight into the student project and its topic area. Taking these considerations into account, task list, event calendar, and the project page as a container for the aforementioned features seem to be appropriate refinements of "task management system" in Chickering and Ehrmann's [1996] technology list, however, there is only inconclusive evidence in favour of this claim and more research is needed to verify that it holds.

Provision of Prompt Feedback Feedback is the result of the monitoring process and vital for student learning as it enhances their self-reflection and self-assessment process [Chickering and Gamson, 1987], which are also core aspects of self-regulated learning. System features supporting feedback are (i) weekly progress feedback, (ii) event attendance feedback, provided that meetings were administered online, and (iii) various feedback visualisations: graphs and charts, the ranking table, and a list of past feedback on the project page. Furthermore, features such as email notifications enable feedback to be communicated beyond the boundaries of the system and regardless of the user's current system login state. Chickering and Gamson [1987] do not define the term "prompt" but suggest that feedback should be provided timely and regularly during in the learning process, not just at the end of it. The system meets these requirements: progress feedback was provided on a weekly basis and by different users (students, monitors, supervisors), and event attendance feedback after every meeting.

In this context, self-assessment – the outcome of self-reflection – is when students (a) take stock of their progress, (b) receive information about other people's perception of their progress, and (c) establish discrepancies between these two. This assessment is dependent on the student's degree of self-regulation as mentioned earlier in this chapter.

Chickering and Ehrmann [1996] propose the use of electronic mail as well as tools for performance recording and analysis for implementing this principle. The web-based monitoring system falls into the latter category. Statistical analysis has shown that the technology list can be refined and extended using email notifications, progress and event attendance feedback, visualisations thereof, and a news feed:

1. *Email notifications* were found to be one of the main system use triggers, hence electronic mail cannot only be used for direct feedback communication but also for notifying users of an online feedback activity. A correlation analysis of feedback submissions and user logins has shown that monitor progress report submissions triggered students to log onto the system, and student progress report submissions also triggered monitors and supervisors to log on. Conversely, supervisor progress report submissions do not correlate with student system logins. Plots of submissions against system logins also revealed that user response to submissions was relatively prompt: students reacted to monitor feedback on the same day it was submitted.

2. There is a statistically significant and positive relationship between both *progress and event attendance feedback* and student's self, monitor, and supervisor-rated weekly student progress ratings. These ratings also correlate positively and significantly with students' dissertation mark, indicating that they accurately reflect student achievement. Therefore, both progress and event attendance feedback tools strongly support the provision of prompt feedback. However, future work might want to look at new ways of measuring student progress, for example, by considering the percentage of completion of tasks in the virtual task list. This requires

the task list to be more intuitive to use, appropriate import and export tools, and encouragement from faculty staff so that students make more use of this feature.

3. The list must be extended by *tools for visualising feedback* or any user activity associated with the provision of feedback. It has been shown that performance histograms and trend graphs are positively related with students' overall progress and achievement. Furthermore, a ranking table was provided, showing the relative performance of the student against their peers using a simple score. The news feed visualises – among other things – all user activity which is associated with feedback, for example, when a monitor submits feedback on a student. Students who interacted more with the news feed also reported higher overall system helpfulness for keeping contact with monitors/supervisors, obtaining progress feedback, and overall project management.

Communicating High Expectations The communication of high expectations is proposed for the purpose of motivating students at all achievement levels equally and for encouraging them to make extra efforts. In this study, a web-based monitoring system was used in combination with a monitoring scheme in the context of MSc summer projects. This setting enables three ways of communicating high expectations. Firstly, a dissertation marking scheme clearly outlining the project assessment criteria was in place. Secondly, weekly supervision and monitoring meetings provided regular opportunities to directly communicate expectations in face-to-face conversations and group discussions, enabling a swift mitigation of discrepancies between existing (qualitative and quantitative) standards and student achievement. Thirdly, the web-based monitoring system acted as an electronic recording and communication platform, supporting information exchange between user roles and direct feedback submission. Feedback could be used for the communication of high expectations.

Monitoring meetings took place outside the scope of this research study, and no data was collected during meetings. Therefore, this work will focus on the feedback submitted using the online monitoring system, particularly the textual content of feedback from monitors and supervisors; these were the people who evaluated whether standards regarding student progress, motivation, and both quality and quantity of the dissertation were met. The purpose of communicating high expectations is to motivate students, therefore correlations between feedback and student motivation ratings were analysed. For this purpose, textual comments submitted together with weekly ratings were examined regarding positive as well as negative remarks about student achievement, reports about extraordinary achievements (success stories), and recommendations for improvement and/or problem solving. It was found that there is a positive and significant relationship between the submission of positive remarks and self as well as supervisor-rated average weekly student motivation; the effect on self-rated student motivation was slightly higher. On the other hand, negative remarks do not seem to have any effect on student motivation, that is, neither negative nor positive correlations were found. It is likely that such comments led to higher student effort, followed by positive remarks and higher student motivation in the following weeks. Success stories also had a positive effect on self-rated student motivation. This is not surprising as such students were unlikely to encounter serious problems in their project and would report good progress and motivation throughout. Conversely, no such correlations were found for monitor/supervisor recommendations.

Apart from feedback comments, high expectations could be communicated using weekly ratings and automated system features encouraging students to make extra efforts. More specifically, visualisations of ratings such as charts and rankings implicitly communicate expectations as they picture a student's performance relative to the average. Typically, self-regulated students will strive to perform better than the average. Furthermore, email notifications were provided to remind students of (i) upcoming meetings, (ii) to submit weekly progress reports, (iii) to indicate whether they attended a meeting, (iv) to participate in group meetings (after absence in past meetings), and (v) to keep their project data (tasks, events, etc.) up to date at all times. The message behind these reminders is that students are expected to be organised so that they make better achievements. Statistical analysis presented in section 6.2.2.4 and discussed in section 6.4.1.2 on page 223 revealed that the more feedback supervisors provided to students the higher their dissertation mark. No such relationship was found with monitor feedback, possibly because supervisors have a much better insight into the project and their feedback is therefore valued higher by students. Charts and graphs also positively correlate with the student dissertation mark and average weekly motivation ratings. Similarly, the number of event attendance feedback submissions by supervisors correlates positively with students' self-rated motivation.

Regarding the implementation of this principle, Chickering and Ehrmann [1996] suggest the use of tools for demonstrating real life situations, large data sets, and the Web for peer evaluation. The web-based monitoring system, although not designed for peer evaluation, falls into that last category. Instead, it provides tools for self-evaluation and feedback from monitors and supervisors. There is conclusive evidence that positive comments from monitors and supervisors about student achievement provided together with weekly ratings had a positive effect on student motivation, while negative remarks did not have a negative effect. The combination of such comments was typically used to communicate high expectations. However, more research is required into the effects of detailed textual feedback, more sophisticated ways of measuring student motivation, and into ways of evaluating how precisely high expectations are communicated by faculty staff. Moreover, progress and event attendance feedback tools and visualisation of feedback data support the communication of high expectations. Prior research and subjective user feedback suggest that this effect can be further increased by implementing feedback in a more dialogic way, enabling users to comment directly on feedback artefacts. Usage statistics also show that support for feedback comment generation might help increase the number of textual comments submitted with progress ratings, enhancing the overall quality of feedback.

7.3 Monitor Effects

The role of monitors is one of the central aspects of the web-based monitoring system as well as the monitoring scheme. It was analysed whether monitor behaviour had significant effects on that of students in terms of academic achievement, motivation, progress, and system use.

It was found that there is a positive and significant relationship between monitor system use and that of students. In more detail, student activity was mainly triggered by monitor progress report submissions, their activity on the group page, and submissions of event attendance feedback. In contrast, monitor activity was triggered by student activity on the group page, the event calendar, the project page, and their submissions of event attendance feedback. Similarly, email notifications received by users correlate positively with their activity on the system, particularly their system logins, which were positively affected by event reminder emails, attendance feedback reminder emails, follow-up reminders sent to students who failed to attend a series of consecutive monitoring meetings, event news feed emails, event attendance and progress feedback submission notifications, and project task creation notifications.

What is more, there are statistically significant between-monitor differences in system use and student achievement. In other words, students attended to by some monitors received significantly higher dissertation marks and used the system more often on average. A positive tutor effect on student attainment was already reported in related work [Cohen et al., 1982]. Furthermore, a plot of student activity against that of monitors and supervisors over time also shows that they are very much in line with one another, that is, usage patterns between user roles matched to a considerable extent. This suggests that the system – in combination with the monitoring scheme – successfully supported bidirectional interactions and information exchange between user roles. Regarding weekly progress and motivation ratings, it was found that student, monitor, and supervisor ratings correlate strongly and significantly, while the effect sizes of correlations with monitor ratings are slightly (but not significantly) lower. This indicates that student perception of their motivation and project progress was in line with that of supervisors, while that of monitors differed at times, possibly because monitors attended to a larger group of students, were less familiar with the project topic area, and spent less time on average with each student in their group(s) compared to supervisors. Consequently, monitor feedback was less accurate regarding students' "real" motivation and progress.

In summary, there is partial evidence for monitor (and partially supervisor) behaviour having a significant effect on student performance and system activity, while average weekly motivation and progress ratings remained unaffected. There also exist similar time-related usage patterns for all three user roles, suggesting that the system facilitated user interactions and information exchange, which was its primary aim. Prior work has also looked at the effect of tutor expertise in the subject area on their students [Silver and Wilkerson, 1991; Schmidt and Moust, 1995; Dolmans et al., 1996]. Although it can be assumed that most monitors were competent in the subject area of their students, detailed data on their expertise and in-group behaviour was not collected. More research on feedback and monitoring system support for heterogeneous tutoring groups is necessary to gather conclusive evidence on this matter.

7.4 Summary

The main focus of this work is the evaluation of feature impact on self-regulated learning in the context of MSc summer projects and their support for four out of seven principles for good practice proposed by Chickering and Gamson [1987]. For this purpose, a web-based monitoring system was used in combination with a monitoring scheme over a period of 17 weeks in a quasi-experimental research study. Data was collected in system logs, from questionnaires, and by using informal semi-structured interviews. Based on the model of self-regulated learning presented by Zimmerman [2011] and other related work (see Chapter 2), four central learning aspects were identified: (i) motivation, (ii) time management, (iii) progress awareness, and (iv) monitoring. A set of (partially overlapping) system features was designed to support these learning aspects.

The statistical data analysis revealed that there are positive and statistically significant relationships between student use of features supporting motivation (weekly progress and motivation ratings, charts and graphs, ranking table, and news feed) and students' average weekly motivation and project progress ratings as well as their dissertation mark. Inconclusive evidence also exists for time management features (project page, task list, event calendar) having a positive effect, although both events and tasks were barely used by students. Furthermore, progress awareness features (charts and graphs, ranking table, news feed), in particular performance histograms and the performance trend graph were found to be effective regarding student achievement and motivation. Finally, monitoring features (progress and event attendance feedback, progress visualisations, and communication features) also partially affected student performance, motivation, and progress in a positive way.

Most features were also found to be suitable for extending and/or refining the list of technologies implementing the seven principles by Chickering and Ehrmann [1996]. In more detail, progress feedback and visualisations were found to encourage student-faculty contact. Progress feedback, the project page, and email notifications implement prompt feedback. The project page support the emphasis of time on task. Finally, progress and event attendance feedback including textual comments, visualisations, the ranking table, and email notifications are suitable for communicating high expectations. Other principles were supported implicitly by the monitoring scheme, which was not the primary focus of this research and thus not analysed.

What is more, there is some evidence for monitors affecting student system activity and their dissertation mark, while no between-monitor differences were found for weekly motivation and progress ratings. Usage patterns are very similar between user roles, indicating that bidirectional information exchange was supported by the system.

Finally, features were ranked as to their impact on student self-regulated learning and concrete effects on the four technology-supported learning aspects. Highly ranked features were weekly student performance histograms, the home page, the ranking table, the project page, and progress feedback. To exemplify possible system effects on self-regulated learning and to explain the underlying self-regulatory processes based on Zimmerman's [2011] model, a narrative case study was provided using three sample students.

Future work includes (i) a thorough review of progress ratings and how they can be measured more accurately and intuitively, (ii) a deeper system integration into other existing teaching and learning support systems, (iii) extended research into the importance of monitors and supervisors for encouraging system use, (iv) the enhancement of communication features, and (v) more sophisticated and interactive student performance visualisations.

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Appendix A

Questionnaires

A.1 Device and Calendaring Technology Survey Questionnaire

This online-questionnaire was used to evaluate what devices are available to students in the Department of Electronics and Computer Science (ECS) at the University of Southampton, to evaluate the current use of calendaring software and their features, and to support the department and the university in making decisions with regard to additional functionality to be provided to students. It comprises 11 questions which are listed in the following paragraphs, 2 of which required a textual response. Students had to provide their school login information to gain access to the questionnaire and in order to rule out duplicates. However, their answers were stored completely anonymously.

1. Please indicate which of the following devices you own or have unrestricted access to, and how often you use them. Choose "N/A" for every device you do not own or have only limited access to.
   Possible answers per item: One out of {N/A, Never, Rarely, Sometimes, Often}

   (a) Internet/network-enabled PC/Mac
   (b) Laptop/Notebook
   (c) Netbook
   (d) Windows-powered smartphone or PDA
   (e) Apple iPhone
   (f) Apple iPod Touch
   (g) Android-powered phone (for example Google Android phone, T-Mobile G1 phone)
   (h) Other internet/WiFi-enabled touch-phone
   (i) Other internet/WiFi-enabled PDA

(j) Other mobile phone

2. How often do you carry the following devices with you when you are on the university campus?
   Possible answers per item: One out of {N/A, Never, Rarely, Sometimes, Often}

   (a) Laptop/Notebook
   (b) Netbook
   (c) Smartphone, PDA, or touch-phone
   (d) Mobile phone

3. Which of the following calendaring software do you use and how frequently?
   Possible answers per item: One out of
   {Never, Once every couple of weeks, Once a week, 2-4 times a week, Daily}

   (a) Microsoft Outlook
   (b) Microsoft Calendar (on Windows Vista)
   (c) Microsoft Outlook Web Access (as provided by the university)
   (d) Mozilla Sunbird
   (e) Google Calendar
   (f) Apple iCal (on Mac)
   (g) Calendaring software on mobile phone, smartphone, or PDA

4. Which of the following calendaring software features do you use and how frequently?
   Possible answers per item: One out of
   {Never, Once every couple of weeks, Once a week, 2-4 times a week, Daily}

   (a) Appointments/Events
   (b) Tasks
   (c) Collaborative scheduling of group meetings
   (d) Reminders
   (e) Contacts
   (f) Email for organising meetings

5. When planning and organising your studies, which one of the above applications do you use the most?
   Possible answer: Exactly one out of the following items

   (a) I do not use any calendaring applications for planning my studies
   (b) Microsoft Outlook

(c) Microsoft Calendar (on Windows Vista)
(d) Microsoft Outlook Web Access (as provided by the university)
(e) Mozilla Sunbird
(f) Google Calendar
(g) Apple iCal (on Mac)
(h) Calendaring software on mobile phone, smartphone, or PDA
(i) Other

6. Please rate how helpful you find the following software features with regard to planning and organising your studies, keeping track of deadlines, personal time-management and so on. (1 = not at all helpful, ..., 5 = extremely helpful)
   Possible answers per item: One out of $\{1, 2, 3, 4, 5\}$

   (a) Appointments/Events
   (b) Tasks
   (c) Collaborative scheduling of group meetings
   (d) Reminders
   (e) Contacts
   (f) Email for organising meetings

7. Please rate your agreement with the following statements (1 = strongly disagree, ..., 5 = strongly agree):
   Possible answers per item: One out of $\{1, 2, 3, 4, 5\}$

   (a) I consider myself a good time-manager.
   (b) I often struggle to meet deadlines.
   (c) I have missed deadlines in the past.
   (d) I can estimate the time I need for studying a subject or performing a task fairly accurately.
   (e) Contemporary calendaring software lacks features supporting learning and studying.

8. Please explain briefly how you currently plan your studies or manage your time:
   Possible answer: Any text

9. On a scale from 1 to 5, how would you rate the helpfulness of the following features in student organiser software? (1 = not at all helpful, ..., 5 = extremely helpful)
   Possible answers per item: One out of $\{1, 2, 3, 4, 5\}$

   (a) Importing and exporting tasks and appointments to your personal calendaring software (such as Outlook, Sunbird, and so on)

(b) Scheduling meetings with your tutor/supervisor

(c) Scheduling group meetings and organising study groups

(d) Organising who does what in group assignments

(e) Observing the progress of other group members when working on group assignments

(f) Automatically estimating the time to commit to a task based on your personal preferences and learning style

(g) Keeping track of your own progress and receiving warnings when tasks become critical

(h) Knowing where your friends and colleagues are on the campus (for instance, on a virtual map)

(i) Finding people who can help you based on their interests and experience and locating them on a virtual map

(j) Attaching geographical locations to tasks and meetings and being reminded when you are in the area

(k) Finding learning resources nearby which you can use for achieving a task

(l) Pinning resources you have discovered on a virtual map and sharing them with your group or everybody

(m) Rating and annotating such resources, for example, as for their usefulness

10. Are there any other features you would like such a student organiser system to provide? If yes, please make suggestions:
Possible answer: Any text

11. If the university/school provided coursework hand-in dates, deadlines, and timetabling information in a format which can easily be imported into your calendaring software, would you make use of them?
Possible answers: One out of {Yes, No, Don't know}

A.2 MSc Project Monitoring Closing Questionnaire

This section gives an outline of the online closing questionnaire of the second research study. Two different versions of the questionnaire were used, one for students, and one for their monitors.

A.2.1 Student Questionnaire

A.2.1.1 Student Motivation

1. Please rate to what degree the following features motivated you to work harder on your project. Possible answers: one out of
{(0, N/A), (1, Did not motivate at all), ..., (5, Motivated very much) }

    (a) Dashboard and statistics charts
    (b) Ranking table
    (c) News feed
    (d) Email notifications
    (e) Progress feedback given by myself
    (f) Progress feedback given by monitor
    (g) Progress feedback given by supervisor
    (h) Event attendance feedback given by my supervisor/monitor
    (i) Task list on project page
    (j) Comments/announcements on group page

2. Please rate your agreement with the following statements. Possible answers: one out of
{(1, Do not agree at all), ..., (5, Fully agree)}

    (a) The meetings with my monitor were helpful to me
    (b) My monitor and/or supervisor picked me up on progress feedback I submitted through the MSc Information System
    (c) The MSc Information System made me more aware of my peers' progress compared to mine

A.2.1.2 Project Management Capabilities and Communication

1. How often did you meet with your monitor? Possible answers: one out of

    {(1, Never), (2, When I needed to), (3, About every 3rd week),
    (4, About every 2nd week), (5, About every week)}

2. Please rate the overall helpfulness of the following features for managing your MSc project. Possible answers: one out of
{(0, N/A), (1, Not helpful at all), ..., (5, Very helpful)}

    (a) Dashboard and statistics charts

(b) Ranking table
(c) News feed
(d) Email notifications
(e) Progress feedback given by monitor
(f) Progress feedback given by supervisor
(g) Event attendance feedback given by monitor or supervisor
(h) Task list on project page
(i) Event/meeting organisation and calendar
(j) Event and/or task data export
(k) Comments/announcements on group page

3. Please rate the helpfulness of the following charts in terms of whether they helped you assess your own performance and compare yourself to other students. Possible answers: one out of
$\{(1, \text{Not helpful at all}), \ldots, (5, \text{Extremely helpful})\}$

    (a) This and last week's rating histograms
    (b) The graph plotting ratings over time
    (c) The event attendance graph
    (d) The graph plotting your report metrics over time
    (e) The chart displaying your progress on milestone tasks
    (f) The chart displaying total, complete, incomplete, and overdue tasks

4. Please rate your agreement with the following statements. Possible answers: one out of
$\{(1, \text{Do not agree at all}), \ldots, (5, \text{Fully agree})\}$

    (a) The MSc Information System helped me to keep myself organised
    (b) The MSc Information System helped me to communicate problems to my monitor or supervisor
    (c) The MSc Information System helped me to keep in contact with my supervisor/monitor while I myself or they were on holidays
    (d) I used the MSc Information System as a starting point to contact other students
    (e) Overall, the MSc Information System enhanced my MSc project management

5. Did you use any other tools for managing your MSc project apart from the MSc Information System? Possible answers for each item: $\{(1, \text{Yes}), (0, \text{No})\}$

    (a) Offline? If yes, please specify.
    (b) Online? If yes, please specify.

A.2.1.3 General Feedback

1. What needs to be changed in the MSc Information System to make it more useful to you as a student?

A.2.2 Monitor Questionnaire

1. Please rate the overall helpfulness of the following features for monitoring MSc projects. Possible answers: one out of
   $\{(0, \text{N/A}), (1, \text{Not helpful at all}), \ldots, (5, \text{Extremely helpful})\}$

   (a) Dashboard and statistics charts
   (b) Ranking table
   (c) News feed
   (d) Email notifications
   (e) Progress feedback
   (f) Event attendance feedback
   (g) Event/meeting organisation (calendar)
   (h) Comments/announcements on group page
   (i) Event data export

2. Please rate your agreement with the following statements. Possible answers: one out of $\{(1, \text{Do not agree at all}), \ldots, (5, \text{Fully agree})\}$

   (a) The MSc Information System helped me to keep track of students' progress
   (b) The MSc Information System helped me point out problems to the student and their supervisor
   (c) The MSc Information System helped me to monitor student progress while I myself or they were absent (e.g. on holidays)
   (d) The MSc Information System enabled me to detect problems in individual student projects
   (e) Overall, the MSc Information System enhanced MSc project management

3. Did you use any other tools for MSc project monitoring apart from the MSc Information System? Possible answer per item: $\{(1, \text{Yes}), (0, \text{No})\}$

   (a) Offline tools? If yes, please specify.
   (b) Online tools? If yes, please specify.

4. What needs to be changed in the MSc Information System to make it more useful to you?

Appendix B

Ethics Review Documentation

Ethics Committee Reference Number: **N/09/09/02**

B.1 Introduction

This document serves as a documentation for a trial which is planned to take place in the upcoming academic year (starting in October this year). The study is not funded, not submitted for funding, and not subject to ethical review elsewhere.

In the first instance, the trial targets undergraduate students in their first year, studying on a Computer Science or ITO degree in ECS, such as students in modules COMP1004 (Programming Principles) and INFO1016 (Information Technology and Systems). However, it will be necessary to repeat the experiment with more experienced students afterwards in order to compare the results with those of the first trial.

The trial involves the target group to actively use a task-based, location-aware time management system over a period of at least one term. The system is completely web-based and can be used on any computer workstation, laptop, netbook, and any other web-enabled mobile device students have access to. It provides the following set of features:

- Joining and leaving virtual study groups, whereby a module is itself a study group. New groups can be created and managed autonomously by students.
- Planning and organising study tasks (assignments, group work, and so forth) within groups (collaborative tasks) and individually (individual tasks). This includes creating sub-tasks and defining their interdependency, and recording progress on such tasks. Tasks and sub-tasks created by individual students outside of the group context are always private, i.e. its data is not visible to other students. However, progress on such sub-tasks counts towards the completion of the parent task, and if the parent task is defined in a group (collaborative task, assignment, and so on), other students can monitor the overall progress on the corresponding parent task.

- The system flags tasks which become critical by using a colour-code (red, yellow, green).
- Students can create their personalised daily work set based on the tasks they defined. This information is shared with other students who are members of the same groups.
- Locating other people in the same group or sub-group and those working on the same assignment on a virtual map. This is achieved by automatically detecting the current geographical location based on WiFi hotspots in the area. Alternatively, if such data is not available, students can manually pin their current position on the map.
- Progress made on tasks is published so that other users in the same group can see how many people are currently working on the same tasks, when people start on a task, and compare how different groups perform on the same task. Such information is only made accessible to group members.
- Managing and tagging resources on a virtual map and linking them with tasks and groups.
- Students can provide contact details and a profile picture which are displayed on the map and thus shared with members of the same groups. The provision of one (primary) email address is compulsory, all other data (such as telephone numbers, instant messaging screen names, web addresses, and other additional email addresses) is optional.

The system is considered completely noninvasive, and there is no risk of harm involved. The remainder of this report provides details about research methodology, trial objectives, data protection and anonymisation, risks and their mitigation, and technical system particularities.

B.2 Study Methodology

B.2.1 Objectives

The objectives of the trial are as follows:

- Measure students' motivational state during the experiment and to test whether there are any relationships between their motivational state and the activities they performed in the system
- Measure the effect of using the time management system on their academic performance (marks) compared to those students who did not use the system

- Test the hypothesis that the disclosure of locational data in combination with information on students' task progress facilitates spontaneous study group formation and collaboration, and interactions between participants
- Test the effect of task progress disclosure on student behaviour. In particular, it is of interest if such information can give students clues about when to start on a task and whether this results in better study organisation
- Compare subjective data (gathered from questionnaires) with objective data (marks, coursework hand-in statistics, system logs, and so on) to evaluate whether the system can help reduce stress and lead to a better learning experience
- Find a relationship between student learning style and temporal measures gained from task progress reports
- Examine whether and how system user behaviour changes over time, and whether there are significant differences between the behaviour of first-year and more experienced users
- Compare the performance after the trial to historical performance data of previous academic years (C-BASS data, marks)

B.2.2 Trial Setup

The trial requires each student to sign up. For the trial group, this means giving consent to using the system in the designed way and approving of task progress data and their geographical location being disclosed as described above. Furthermore, all activities they make in the system are logged and used for analysis later (after anonymisation). For the control group, this means that participants agree that their academic performance data and course hand-in system statistics can be used during analysis. For each member of the trial group, a user account with a strong random password will be created. This log-in data is then provided to students, and they are asked to change their password upon first log-in.

Provided that a sufficient number of students signs up for the trial, the participants will be randomly assigned to either the trial or the control group. Alternatively, participants can choose whether they want to be part of the trial or control group, whereby members of the trial group will use the software and those of the control group will not. At this point, all participating students will be asked to provide their email address and student ID number, and to fill in Felder & Silverman's ILS learning style questionnaire. The number of students in each group is dependent on the total number of students who are willing to participate and their choice of group.

Dependent on the state of the software system at the beginning of the academic year, a lightweight trial is considered as an alternative. In that case a group of students can sign up to try the software and provide feedback on it, while the actual trial takes place at a later time when the system is stable. Data collected during this pre-trial can be used for analysis.

Signing up is completely voluntary, that is, students are not forced to participate and they can revoke their decision at any time, which will result in all logged system data linked to them being destroyed. However, students will be encouraged to participate by pointing out the benefit of using the system; no extrinsic inducement (for example rewards) will be used.

As the study is intrusive, a debriefing session will be held at the end of the trial. The scheduled date and time is Friday, 23 April 2010, at 5:00pm in building 32 (seminar room). In this session, students will be presented with the primary results of the study, i.e. which of the objectives (see B.2.1) have been met and other interesting findings. These results will also be made available as a handout. Furthermore, they will be given the opportunity to provide feedback on the system and the study itself.

B.2.3 Data Collection

The trial objectives mentioned in B.2.1 will be tested by using the following tools and sources:

- Data logs: all student activity in the software is logged to a database. This includes progress made on tasks, joining groups, and the frequency of using certain features.
- Performance data: this includes access to the C-BASS hand-in system and the marks at the end of the term.
- Historical performance data: for comparative analysis, access to C-BASS hand-in data and marks of previous academic years is necessary.
- Questionnaire results: the (subjective) feedback given through questionnaires will be compared with objective data mentioned above.
- Debriefing results: the (subjective) feedback given through personal feedback during debriefing will be used in combination with questionnaire results.

The above data is linked by using the student's university ID number, and later anonymised as described in section B.3.

B.3 Data Protection and Anonymisation

Since data from different sources (C-BASS, marks, logs) must be linked in order to enable statistical analysis to be performed, the student ID number will serve as an initial unique case identifier. All personal information linked to this number (names and so on) will be removed from the data before the analysis starts. This includes all names, contact information, and other personal data which could be used to identify an individual in the group of participants. In the next step, a unique number will be created from scratch for each student, replacing the student ID number. The association between student ID number and the newly created case number, used temporarily in the anonymisation process, will be kept separately from subject data used for analysis (see B.2.3 for details). Course leaders or moderators will not access this data for purposes other than those described in section B.2.1.

All historical performance data (C-BASS hand-in statistics and marks) is completely anonymised, that is, all student identifiers and personal data is removed from the analysis data set prior to analysis and after it has been linked using the student ID. The links between student ID and the generated case number are stored separately for administrative purposes.

All data is held within the ECS demilitarised zone and benefits from ECS system security. No copies will be stored on any other computer outside ECS or any external storage devices. Data in paper form will be locked away securely and will only be available to the people administering the trial. After the analysis is completed, only anonymised data is retained, i.e. all personal data such as ID numbers, names, contact data, and all other data subject to the Data Protection Act is completely removed and destroyed from all systems and all paper documents containing this data will be shredded. Furthermore, the anonymised data set used during analysis will not be published unfiltered and without written consent of the participants.

B.3.1 Data Description

The following list provides an overview on personal student data collected during the experiment:

Student ID The student ID number is used to identify the origin of data collected from different sources, for example, the C-BASS hand-in system and the system logs, as well as performance data (marks). The student ID will be replaced by a unique case number during the anonymisation process, and all data which could be used to establish relationships between this case number and the original student ID will be destroyed.

Name The student name, i.e. their first and last name, is used in the task management system to identify individual students and to make them recognisable to their peers using the same system. It is stored securely in a database which is hosted on a virtual machine in ECS (demilitarised zone), and stripped from the data set prior to analysis.

Gender Students can choose to provide their gender, enabling gender-specific analysis later on, however, they can choose not to disclose this information.

Learning Style The student's learning style is assessed prior to the start of the experiment by using the Felder & Silverman ILS questionnaire. This information is used to find relationships between learning style and time management behaviour of students.

Location The system uses a geographical location detection system which works on the basis of WiFi hotspots in their area. These hotspots send out a unique fingerprint, which is matched against a database of geographical locations in order to determine the user's precise position. This positional data is exposed to other users who are members of the same groups by displaying it on a virtual map. If the device used by the participant does not support WiFi access, the positioning is performed based on their IP address, which yields a fairly imprecise location. In that case the user can manually set their location on the map.

Task Progress System users will use the system for creating tasks and sub-tasks. There are group and individual tasks, the progress on former tasks will be disclosed to other members of the same group, whereby individual tasks are private and progress reported on them will not be published to other users. However, if the individual task is created as sub-task of a group task, progress on that individual task counts towards the group task, and progress data will be disclosed in the context of the group task. This information does not include any data other than the task progress (percentage of completion).

Contact Data Students are asked to provide at least their university email address and to give their consent to it being made available to other system users. Furthermore, students can provide phone numbers, web addresses, instant messaging screen names, and other email addresses. This data is optional and can be managed autonomously by students. The university email address also serves as a log-in name to the system.

Activities All activities performed by students in the system are logged for the purpose of analysing user behaviour. Activities are user actions such as joining or leaving a group, providing feedback on a task, changing their geographical location, and all data related to task progress and completion in general, that is, the actual time compared to the planned time on task.

B.3.2 Risks

The study could be considered intrusive in the sense that some private or behavioural student data is disclosed to other group members during the trial. Hence, there is a very small risk that such data is misused by other users, or its publication might cause discomfort such as peer pressure. As students are asked to use the system over a period of at least one term, they might also feel that their engagement in the trial has a negative effect on their time management with regard to other modules. On the other hand, the system is designed to support students in managing their tasks, and it provides useful information about how many of their peers are involved in the same activities. It also encourages them to interact with their peers and could therefore have a supporting and motivating effect.

To mitigate these risks, students are given complete freedom over the time they invest in the trial. They can also decide to withdraw at any time without any negative consequences arising from their decision. The consent information provided at the start of the trial mentions the above risks and also describes what data students need to provide and how it will be used and stored in the system.

All confidential data such as marks and hand-in statistics are anonymised prior to analysis in order to minimise the risk of such data being misused by a third party. During the trial, this data is password-protected and stored on ECS systems only.

Appendix C

List of Variables for Data Analysis

The following list provides a description for each of the 719 variables in the data set used for analysis in the second research study (see Chapters 5 and 6).

SubjectNo String(3), nominal, $\{000, \ldots, 380\}$. The subject number used after all personal data was removed from the original system database. The subject number was also used to link data originating from the same system user.

APC.$w.r$ Numeric, scale; $w, r \in \mathbb{Z}^+$, $w \in [25, 41]$, $r \in [1, 3]$. The number of pages in the appendix of the student report as submitted in weekly feedback (week 25 to 41, 2010) by students themselves ($r = 1$), monitors ($r = 2$), and supervisors ($r = 3$).

AQ.$w.r$ Numeric, ordinal; $w, r \in \mathbb{Z}^+$, $w \in [25, 41]$, $r \in [1, 3]$. The quality of the student's report appendix on a scale ranging from 0 to 5, where 0 denotes "not seen", as rated by students ($r = 1$), monitors ($r = 2$), and supervisors ($r = 3$).

BQ.$w.r$ Numeric, ordinal; $w, r \in \mathbb{Z}^+$, $w \in [25, 41]$, $r \in [1, 3]$. The quality of the student's report body on a scale from 0 to 5 as rated by students ($r = 1$), monitors ($r = 2$), and supervisors ($r = 3$).

BWC.$w.r$ Numeric, scale; $w, r \in \mathbb{Z}^+$, $w \in [25, 41]$, $r \in [1, 3]$. The word count of the student's report body as submitted by students ($r = 1$), monitors ($r = 2$), and supervisors ($r = 3$).

OP.$w.r$ Numeric, ordinal; $w, r \in \mathbb{Z}^+$, $w \in [25, 41]$, $r \in [1, 3]$. The student's overall project progress rated on a scale from 0 to 5 by students ($r = 1$), monitors ($r = 2$), and supervisors ($r = 3$).

SM.$w.r$ Numeric, ordinal; $w, r \in \mathbb{Z}^+$, $w \in [25, 41]$, $r \in [1, 3]$. The student's motivation rated on a scale from 0 to 5 by students ($r = 1$), monitors ($r = 2$), and supervisors ($r = 3$).

Event.x Numeric, scale. The number of event-related system interactions of each user, where $x \in$ {Delete, Details, Insert, Update, Total} denotes the action performed on the event by the specified user.

Export.x Numeric, scale. The number of data export-related system interactions of each user, where $x \in$ {Delete, Index, Insert, Total} denotes the action performed on the data export by the specified user.

Group.x Numeric, scale. The number of group-related system interactions of each user, where $x \in$ {Index, Update, Total} denotes the action performed on the group by the specified user.

Help.Show Numeric, scale. The number of times each user requested help on a particular feature for which a help text was provided on the system.

Home.x Numeric, scale. The number of home page interactions of each user, where $x \in$ {Home, Logout, Total} denotes the action performed on the page by the specified user.

News.x Numeric, scale. The number of news feed interactions of each user, where $x \in$ {GotoEvent, GotoGroup, GotoGroupNotes, GotoProject, GotoTask} denotes the action performed by the specified user.

Project.x Numeric, scale. The number of project page interactions of each user, where $x \in$ {Index, Update, Total} denotes the action performed by the specified user.

Statistics.Dashboard Numeric, scale. The total number of interactions with any chart or graph by user. The detailed distribution of interactions on each graph is denoted by the Chart.x variable below.

Task.x Numeric, scale. The number of project task interactions of each user, where $x \in$ {Delete, Details, Insert, Update, View, Total} denotes the action performed by the specified user.

User.x Numeric, scale. The number of user-related interactions of each user, where $x \in$ {Login, Profile, RemovePicture, UploadPicture, Total} denotes the action performed by the specified user.

Chart.x Numeric, scale. The number of chart-related interactions of each user, where

$$x \in \{\text{Attendance, Milestone, PerformanceGraph, PerformanceLastWeek,} \\ \text{PerformanceThisWeek, Report, Task}\}$$

denotes the chart requested by the user. The total number of chart-related interactions by user is given in variable Statistics.Dashboard above.

Activity.Total Numeric, scale. The total number of system activities by user, that is, the sum of all feature-specific interactions.

Weekly.Activity Numeric, scale. Like Activity.Total, but divided by the total number of weeks (17) of the study.

qxItem$y$ Numeric, ordinal, The answers of students to the closing questionnaire items with

$$(x, y) \in \{(11, [1, 10]), (12, [1, 3]), (22, [1, 11]), (23, [1, 6]), (24, [1, 5])\}$$

These are mostly ratings between 0 and 5 where 0 denotes "N/A". The questionnaire is outlined in Appendix A.2.1.

q21 Numeric, ordinal. The student's answer to item 2.1 in the online closing questionnaire outlined in Appendix A.2.1.

q31Offline Numeric, nominal. The student's answer to item 3.1 in the online closing questionnaire asking for other offline tools used for MSc project management.

q31Online Numeric, nominal. The student's answer to item 3.1 in the online closing questionnaire asking for other online tools used for MSc project management.

Programme String, nominal. The student's programme of study, that is, the concrete MSc course they were studying.

Rank Numeric, nominal. The user's rank in the hierarchy of system users; this can be 1 (student), 2 (monitor), 3 (supervisor).

AssociationCount Numeric, scale. The number of associations of the corresponding users, for example, with groups, projects, and so on.

OP.Block$x.r$ Numeric, scale. The average overall student project progress of week blocks, where $(x, r) \in \{\{1, 2, 3, 4\} \times \{1, 2, 3\}\}$ with x denoting the week block containing 4 consecutive weeks and r the user rank, that is, student, monitor, and supervisor, respectively. These variables were used in the repeated-measures ANOVA test.

SM.Block$x.r$ Numeric, scale. The average student motivation of week blocks, where $(x, r) \in \{\{1, 2, 3, 4\} \times \{1, 2, 3\}\}$ with x denoting the week block containing 4 consecutive weeks and r the user rank, that is, student, monitor, and supervisor, respectively.

BQ.Block$x.r$ Numeric, scale. The average quality of the student's report body of week blocks, where $(x, r) \in \{\{1, 2, 3, 4\} \times \{1, 2, 3\}\}$ with x denoting the week block containing 4 consecutive weeks and r the user rank, that is, student, monitor, and supervisor, respectively.

AQ.Block$x.r$ Numeric, scale. The average quality of the student's report appendix of week blocks, where $(x, r) \in \{\{1, 2, 3, 4\} \times \{1, 2, 3\}\}$ with x denoting the week block containing 4 consecutive weeks and r the user rank, that is, student, monitor, and supervisor, respectively.

AssBrief Numeric, scale. The number of days the student submitted his project brief (at the beginning of their project) late, that is, after the deadline.

AssDissertation Numeric, scale. The number of days the student submitted their final MSc dissertation late, that is, after the deadline.

AssResearchMethods Numeric, scale. The number of days the student submitted their Research Methods coursework (in the taught part of the MSc) late, that is, after the deadline.

ExtBrief Numeric, nominal, $\{0, 1\}$. Denotes whether the student was granted an extension to the project brief submission deadline.

ExtDissertation Numeric, nominal, $\{0, 1\}$. Denotes whether the student was granted an extension to the MSc dissertation submission deadline.

ExtResearchMethods Numeric, nominal, $\{0, 1\}$. Denotes whether the student was granted an extension to the Research Methods coursework submission deadline.

Activities.w Numeric, scale, $w \in \mathbb{Z}^+$, $w \in [25, 41]$. The total number of user-system interactions in week w, that is, any interaction with any feature of the system in that week.

Activities.Block$x$ Numeric, scale, $x \in \mathbb{Z}^+$, $w \in [1, 4]$. The total number of user-system interactions in week block x comprising 4 consecutive weeks.

Monitor Numeric, nominal. The subject number of the monitor looking after the corresponding student.

OP.Mean.r Numeric, scale, $r \in \mathbb{Z}^+$, $r \in [1, 3]$. The overall average student project progress over all weeks, submitted by the student ($r = 1$), monitor ($r = 2$), and supervisor ($r = 3$).

SM.Mean.r Numeric, scale, $r \in \mathbb{Z}^+$, $r \in [1, 3]$. The overall average student motivation over all weeks, submitted by the student ($r = 1$), monitor ($r = 2$), and supervisor ($r = 3$).

BQ.Mean.r Numeric, scale, $r \in \mathbb{Z}^+$, $r \in [1, 3]$. The overall average quality of the student's report body over all weeks, submitted by the student ($r = 1$), monitor ($r = 2$), and supervisor ($r = 3$).

AQ.Mean.r Numeric, scale, $r \in \mathbb{Z}^+$, $r \in [1, 3]$. The overall average quality of the student's report appendix over all weeks, submitted by the student ($r = 1$), monitor ($r = 2$), and supervisor ($r = 3$).

HasMonitor Numeric, nominal, $\{0, 1\}$. Indicates whether the corresponding student was in a monitoring group and had a monitor assigned.

GroupEventCount Numeric, scale. The total number of group appointments/meetings (usually monitoring meetings) in the user's project calendar.

ProjectEventCount Numeric, scale. The total number of project appointments/meetings (usually supervision meetings) in the user's project calendar.

Score.w Numeric, scale, $w \in \mathbb{Z}^+$, $w \in [25, 40]$. The student's score in the ranking table for each calendar week w in 2010.

Score.Mean Numeric, scale. The average score for each student over all calendar weeks.

TaskCount Numeric, scale. The total number of tasks a student managed in their project task list.

Email.x Numeric, scale. The total number of email reminders/notifications delivered to the corresponding user, where

$$x \in \{\text{Event, EventFeedback, FollowUp, ProgressFeedback,} \\ \text{TaskState, News, Total}\}$$

denotes the type of email sent.

TaughtMark Numeric, scale, $[0, 100]$. The student's pre-test performance, that is, the mark on the taught part of their MSc programme.

DissertationMark Numeric, scale, $[0, 100]$. The student's post-test performance, that is, the mark of their final MSc dissertation.

Recommendation String, nominal. The final outcome of the student's MSc programme. This can be "Pass", denoting that the student has passed the course, "Distinction" if the student has achieved a high mark, and "Refer in Project" if the student has failed and needs to repeat their project.

MarkBeforePenalty Numeric, scale. The student's dissertation mark before the late submission penalty was applied.

MarkAfterPenalty Numeric, scale. The student's dissertation mark after the late submission penalty.

Penalty Numeric, scale. The late penalty or 0 if the student submitted their dissertation by the deadline.

Referral Numeric, nominal, $\{0, 1\}$. Indicates whether the student needs to refer in project.

Diploma Numeric, nominal, $\{0, 1\}$. Indicates whether the student dropped out with a postgraduate diploma (after the taught part).

Distinction Numeric, nominal, $\{0, 1\}$. Indicates whether the student finished their programme with a distinction.

Fail Numeric, nominal, $\{0, 1\}$. Indicates whether the student failed their programme.

Activity.Group Numeric, nominal. The first cluster variable CV_1 as outlined in section 6.3.1 on page 190, using the cumulative percentage of activity count value frequencies.

Cluster3.Activity Numeric, nominal. The second cluster variable CV_2 as outlined in section 6.3.1 on page 190, using the hierarchical single linkage nearest neighbour clustering algorithm.

Cluster2.Activity Numeric, nominal. The third cluster variable CV_3 as outlined in section 6.3.1 on page 190, using the hierarchical Ward method clustering algorithm.

Cluster1.Activity Numeric, nominal, $\{1, 2, 3\}$. The fourth cluster variable CV_4 as outlined in section 6.3.1 on page 190, using the k-means clustering algorithm.

StaffSubjectNo.102 String, nominal. The subject number of the student's project monitor.

StaffSubjectNo.103 String, nominal. The subject number of the student's project supervisor.

Event$x.r$ Numeric, scale, $x \in \{\text{Delete, Insert, Update, Total}\}$, $r \in \{102, 103\}$. The student's monitor's ($r = 102$) and supervisor's ($r = 103$) event-related user-system interactions.

Export$x.r$ Numeric, scale, $x \in \{\text{Delete, Index, Insert, Total}\}$, $r \in \{102, 103\}$. The student's monitor's ($r = 102$) and supervisor's ($r = 103$) data export-related user-system interactions.

Group$x.r$ Numeric, scale, $x \in \{\text{Index, Update, Total}\}$, $r \in \{102, 103\}$. The student's monitor's ($r = 102$) and supervisor's ($r = 103$) group-related user-system interactions.

HelpShow.r Numeric, scale, $r \in \{102, 103\}$. The student's monitor's ($r = 102$) and supervisor's ($r = 103$) help-related user-system interactions.

Home$x.r$ Numeric, scale, $x \in \{\text{Home, Logout, Total}\}$, $r \in \{102, 103\}$. The student's monitor's ($r = 102$) and supervisor's ($r = 103$) home page user-system interactions.

News$x.r$ Numeric, scale; $r \in \{102, 103\}$. The student's monitor's ($r = 102$) and supervisor's ($r = 103$) news feed user-system interactions where x denotes the user's specific news feed interaction with

$$x \in \{\text{GotoEvent, GotoGroup, GotoGroupNotes,} \\ \text{GotoProject, GotoTask, Total}\}$$

NoteNotes.r Numeric, scale, $r \in \{102, 103\}$. The student's monitor's ($r = 102$) and supervisor's ($r = 103$) group note page user-system interactions.

Project$x.r$ Numeric, scale, $x \in \{\text{Index, Update, Total}\}$, $r \in \{102, 103\}$. The student's monitor's ($r = 102$) and supervisor's ($r = 103$) project page user-system interactions.

StatisticsDashboard.r Numeric, scale, $r \in \{102, 103\}$. The student's monitor's ($r = 102$) and supervisor's ($r = 103$) chart and graph user-system interactions.

Task$x.r$ Numeric, scale, $x \in \{\text{Details, Insert, View, Total}\}$, $r \in \{102, 103\}$. The student's monitor's ($r = 102$) and supervisor's ($r = 103$) task user-system interactions.

User$x.r$ Numeric, scale, $x \in \{\text{Login, Profile, UploadPicture, Total}\}$, $r \in \{102, 103\}$. The student's monitor's ($r = 102$) and supervisor's ($r = 103$) user-related user-system interactions.

Total.r Numeric, scale, $r \in \{102, 103\}$. The student's monitor's ($r = 102$) and supervisor's ($r = 103$) total user-system interactions.

NoteCount Numeric, scale. The number of group notes the corresponding user is associated with, because they either created or replied to it.

OwnNoteCount Numeric, scale. The number of group notes the corresponding user created themselves.

ReplyCount Numeric, scale. The number of replies to group notes the corresponding user is associated with.

OwnReplyCount Numeric, scale. The number of replies to group notes the corresponding user has created themselves.

ExportCount Numeric, scale. The number of data exports performed by the user.

AttendedEventCount Numeric, scale. The number of events the user has attended.

TotalEventCount Numeric, scale. The number of events the user is a participant of.

Attendance Numeric, scale. The attendance rate based on attended vs. total events.

SupervisorStudentCount Numeric, scale. The total number of students the corresponding student's supervisor attended to.

DissertationMarkCode String, nominal. The coded dissertation mark as used in education ranging from "A" to "D".

LowDissertationMark Numeric, nominal, $\{0, 1\}$. Indicates whether the dissertation mark is low (50-55%) or higher than that.

CommentLength.Avg Numeric, scale. The average length of free-text comments in weekly progress feedback.

SR.Avg Numeric, scale, $[0, 1]$. The average indicator for the presence of detailed project status reports in textual weekly progress feedback.

QA.Avg Numeric, scale, $[0, 1]$. The average indicator for the presence of questions and/or answers in textual weekly progress feedback.

PR.Avg Numeric, scale, $[0, 1]$. The average indicator for the presence of positive monitor/supervisor remarks in textual weekly progress feedback.

NR.Avg Numeric, scale, $[0, 1]$. The average indicator for the presence of negative monitor/supervisor remarks in textual weekly progress feedback.

IS.Avg Numeric, scale, $[0, 1]$. The average indicator for the presence of remarks about issues or problems regarding the project in textual weekly progress feedback.

OR.Avg Numeric, scale, $[0, 1]$. The average indicator for the presence of organisational remarks in textual weekly progress feedback.

SU.Avg Numeric, scale, $[0, 1]$. The average indicator for the presence of success stories in textual weekly progress feedback.

RE.Avg Numeric, scale, $[0, 1]$. The average indicator for the presence of monitor/supervisor recommendations in textual weekly progress feedback.

M.QxItem$y$ Numeric, ordinal; $x, y \in \mathbb{Z}^+$, $(x, y) \in \{(11, [1, 9]), (12, [1, 5])\}$. The monitor's answers to the online closing questionnaire (see Appendix A.2.2 on page 292). Most answers were picked from a 6-point scale.

M.Q13Online Numeric, nominal, $[0, 1]$. Indicates whether the monitor used other online tools besides the monitoring system for project monitoring.

M.Q13OnlineText String, nominal. Other online tools used by the monitor for project monitoring.

M.Q13.Offline Numeric, nominal, $[0, 1]$. Indicates whether the monitor used other offline tools besides the monitoring system for project monitoring.

M.Q13.OfflineText String, nominal. Other offline tools used by the monitor for project monitoring.

M.Q14 String, nominal. Monitor's suggestions for improving the system and textual feedback from the closing questionnaire.

MonitoringGroup String, nominal. The name of the monitoring group the student was assigned to.

MonitoringGroup.Numeric Numeric, nominal. Same as MonitoringGroup above, but containing an integer number.

Mark.Improvement Numeric, scale. The difference between the student's dissertation mark and their taught mark.

SM.Improvement.b_1.b_2 Numeric, scale. The average difference between student motivation ratings of week blocks b_1 and b_2, where $(b_1, b_2) \in \{(1, 2), (2, 3), (3, 4)\}$.

OP.Improvement.b_1.b_2 Numeric, scale. The average difference between student progress ratings of week blocks b_1 and b_2, where $(b_1, b_2) \in \{(1, 2), (2, 3), (3, 4)\}$.

Supervisor String, nominal. The student's supervisor subject number.

Supervisor.Numeric Numeric, nominal. The numeric representation of the student's supervisor.