Pedagogical Feedback for Computer-based Sport Training

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Abstract

Feedback in Computer-based Sport Training (CBST) may be synthetically designed to allow athletes to practise in a more effective way and enhance their skill acquisition. Little research has integrated pedagogic theory and instructional design with the design of feedback in CBST. To bridge this gap, the paper presents the design of pedagogically-informed feedback for the implementation of a CBST system. The heart of the design is to generate feedback based on the athletes' achievement of their intended training outcome. The pedagogical feedback system measures athletes' performance and compares it with the given training outcomes. The system then identifies the performance's gap and generates feedback to reinforce better performance. A counterbalanced experiment asked student rowers (N = 8) to explore the differences between the pedagogical feedback system and their current feedback system (Sean-Analysis). Pedagogical feedback was at least as good as Sean-Analysis with respect to the level of satisfaction of the athlete. Overall, it can be concluded that the pedagogical feedback appears to be a good model for generating feedback in CBST.

Assessment is a critical catalyst for student learning to measure learning outcomes more formally (Conole and Warburton, 2005). The benefit of computer-assisted assessment (CAA) should be timely, specific, and relevant information provided to each student in respect of their performance. Reviews on CAA conclude that technology enhanced assessment should include the assessment of metacognition, the analysis and assessment of cognitive processes, and the support of reflection and critical thinking skills (Kalz et al., 2008).

Motor skills, although not usually the major part of educational objectives in Higher Education, are components of a distinct type of learning outcome and are essential to learning and teaching in human performance. Cognitive objectives typically involve declarative, procedural, or conditional knowledge. Performance objectives involve precise, smooth, continuous, and accurately timed performances characteristically associated with sport.

CAA in the motor skill domain has become an essential tool for evaluating the technical proficiency of athletes' performance. In traditional sports training, the coach directs and improves the performance of athletes by giving information and feedback on techniques, tactics, and physiological demands. The volume of data generated means it is often not possible for a coach to track all the variables and respond to all the information. Furthermore, the environment of some training (large fields, out of doors, scattered athletes) makes the coaches' exact observation of performance difficult. To overcome these drawbacks, computer-based technology (e.g., virtual reality, motion training systems, and ergometer machines) is used to record athletes' performance (Guang-zhong, 2008, Beetz et al., 2005, Liebermann et al., 2002). Thus, Computer-based Sport Training (CBST) serves as both a stimulus towards and a method for the study of choices that athletes make during athlete-controlled training opportunities.

The development of CBST has made it possible to augment and improve the feedback that athletes receive during training. Feedback systems typically incorporate embedded sensors and devices into the sports equipment and use sensors attached to the athlete to acquire information about learning processes and the achievement of intended performance outcomes. Through feedback, athletes recognize areas of deficiency in their knowledge and skills which they seek to remedy. The aim of this paper is to explore the design of feedback from a technical and pedagogical perspective for the implementation of CBST.

The rest of the paper is organized as follows. First, the paper analyses current feedback design, then presents a framework for pedagogical feedback. A conceptual model of training outcomes, and the process of generating feedback, are discussed. The experiment and its results are presented and discussed to validate the proposed feedback mechanism, and finally some conclusions are drawn.

Current Feedback Design

Feedback to athletes has been identified as a key strategy in motor skill learning. Effective feedback design is associated with feedback that is appropriate, timely, suited to the needs of the situation, and sufficient. Feedback in CBST contributes to learning by allowing athletes to verify their movements, evaluate their progress, and determine the causes of their errors. It also motivates them to remain involved in their training, provided they perceive the feedback as helpful.

The challenge for educational researchers and designers of CBST environments is to determine what constitutes effective and appropriate feedback for athletes in their training trajectory, given the large variety of information that might be provided.

Most research has focused on feedback's role in the cognitive domain (Mory, 2004, Shute, 2008), while less research has focused on designing and implementing feedback in the motor skill domain. Currently, issues of feedback in the motor skill domain via CBST concern: (1) feedback content such as speed, accuracy, movement, time, and reaction time (Baudouin and Hawkins, 2004, Cheng and Hailes, 2008); (2) providing athletes with access to their feedback via an appropriate user interface (Cyboran, 1995); and (3) feedback modality, such as visual, audio, tactile, and haptic (Philo Tan et al., 2003).

Feedback in both the cognitive domain and in motor skill environments is designed to shape the perception, cognition, or action of the learner. However, the design of feedback in the motor skill domain via CBST is typically led by technology and fails to properly consider pedagogical issues. Feedback in CBST is not usually informed by the goals, actions, processes, outcomes, and contexts of a learning and teaching situation.

Thus, for pedagogical reasons, this paper proposes the design of effective feedback that can: (1) support athletes in their achievement of the underlying intended training outcomes, (2) assist athletes in identifying the gaps in their performance, and (3) help athletes to determine performance expectations, identify what they have already learned and what they need to learn next, and judge their personal learning progress.

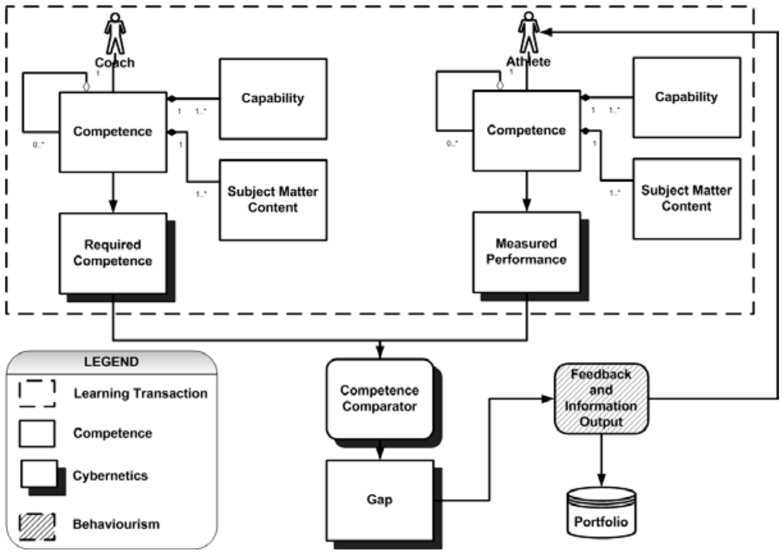

Figure 1: Framework of pedagogical feedback in the motor skill domain

Pedagogical Feedback in CBST

Figure 1 shows the proposed framework for pedagogical feedback. Such a framework illustrates how the principles from learning transactions, competences, cybernetics, and behaviourism might work together to build sound pedagogically-informed feedback in the implementation of a CBST system. Key to the framework is the description of performance goals and the identification of the performance changes needed to achieve them. Such pedagogically designed feedback would allow adaptive training experiences that are tailored to the different needs and characteristics of athletes, especially in terms of their current competence.

The framework can be seen as a lifecycle which aims at the continuous enhancement and development of an athlete's competence. Additionally, it might assist in increasing consciousness of and focus on personal competence development. The main steps of this lifecycle can be identified as follows:

1. Creation of a network of required competences by the coach

Competence models are used to inform the design of appropriate learning activities so as to close the gap between the required competences of a given curriculum and the ones already owned by an individual athlete. In this paper, competence is conceptualised as comprising two components: a statement of capability, and a statement of the subject matter to which the capability applies. The framework suggests that the coach creates the tree or network of desired competences, but this could equally be provided by a coaching or professional organization or association or by a skilled athlete.

2. Gap analysis between required competences and current competence of the athletes

Given an athlete with a particular learning goal that can be interpreted in terms of a network of competences with particular proficiency levels, the competence comparator measures the performance of the athlete and compares it with the required competence. The result is a gap analysis, which yields the required feedback and information output. The feedback generated is based on the results from the assessment that reflect the attainment of the intended learning outcome. During learning, personalised learning activities are continuously monitored and the data collected used for feedback generation. For athletes this implies that they should be advised on the learning possibilities that match their current competence level and that work toward their desired competence level (learning goals), taking into account their restrictions and preferences.

3. Continuous performance monitoring and assessment to confirm improvement.

A portfolio serves several roles in competence development. This paper considers a portfolio as a dynamic collection of authentic and diverse evidence that represents which competences a person has developed over time. It provides (a) profiles of competences, and (b) opportunities for athletes to document their competences in different contexts. Athletes provide evidence through a self-reflection process in which they assign their performances to competences, and reflect on how they acquired such competences. From the pedagogical point of view, this process helps athletes better to understand themselves (knowledge of self) and become better self-directed learners.

Conceptual Model of Training Outcomes in the Motor Skill Domain

Figure 2 and Table 1 represent some rowing training outcomes based on the competence model. The simplest training outcomes structure consists of a pair of procedural skills, one subordinate to the other. The structure describes what the learner must be able to do in order that something else can be learned. The learning relation is identified by the following sentence: "A learner must be able to do 'X' in order to be able to do 'Y'". For example, in order to achieve C0 (able to perform automatically rowing), it is expected that the athletes need to achieve C0.1 (able to perform automatically catch), C0.2 (able to perform automatically drive), and C1 (able to articulate rowing). In order to achieve C0.1 (able to perform automatically catch), athletes should be able to demonstrate C0.1.1 (able to perform automatically grip handles) and C0.1.2 (able to perform automatically positioning shins). The achievement of C0.1 (able to perform automatically catch) preceeds C0.2 (able to perform automatically drive).

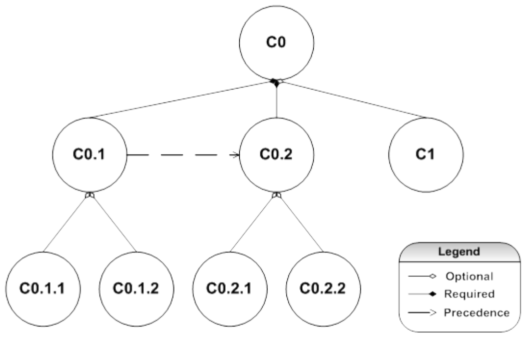

Figure 2: Conceptual model of intended performance

Table 1: Some example rowing competences represented in the competence model

Training Outcomes	Capability	Subject Matter	Proficiency Level
C0	Execute accurately	Rowing	20 -25 strokes per minutes
C1	Articulate	Rowing	15 – 20 strokes per minutes
C0.1	Execute accurately	Catch	40 -45 degrees of flexion
C0.1.1	Execute accurately	Grip handles	80 – 90 psi
C0.1.2	Execute accurately	Positioning shins	90 – 85 vertical

Process of Generating Feedback

Pedagogical feedback involves feedback based on how well athletes achieve their intended training outcomes. To provide such feedback, first the system measures athletes' performance and compares it with the intended training outcomes. The system then identifies the performance's gap and generates feedback to reinforce accurate movement.

Figure 3 illustrates the process of generating feedback based on traversing the competence network.

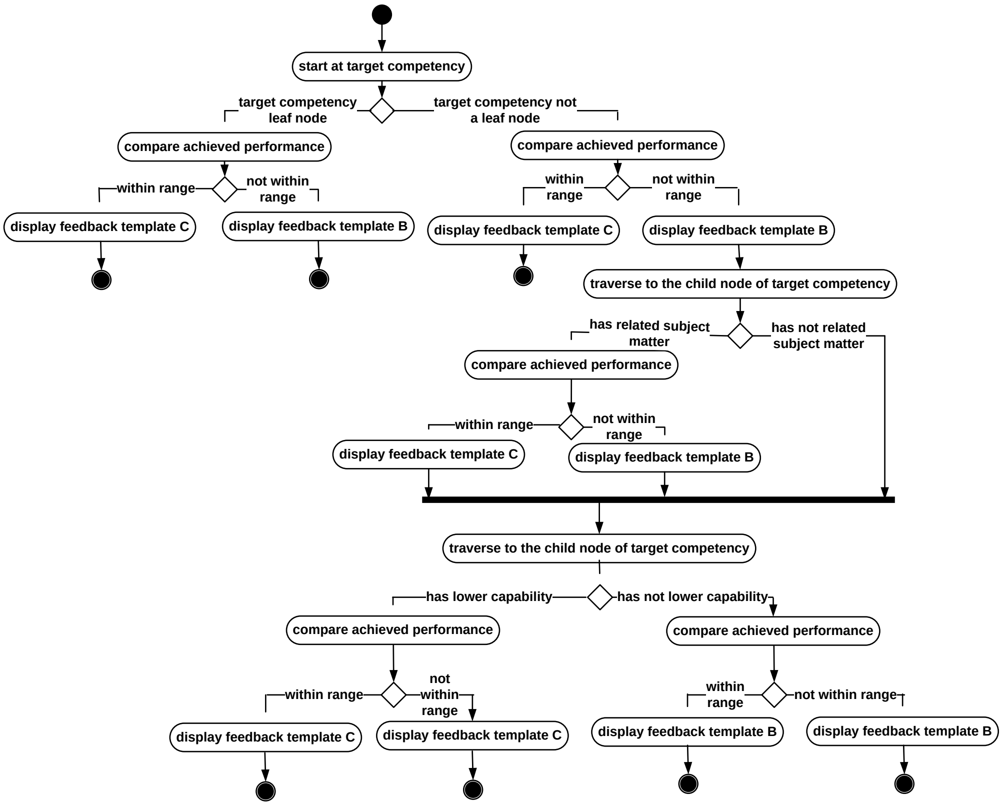

Figure 3: Process of generating feedback

The system starts at the target competence. It gets the achieved performance of the athlete from the sensor data. In this example, achieved performance for rowing is 23 stokes/minute. It gets the required proficiency from the competence network.

To compare achieved performance to the required proficiency, the system looks at the range of the required proficiency. For the example, the range of the required proficiency for rowing is from 21 stokes/minute to 24 strokes/minute. The system then compares the achieved performance to the range of the required proficiency.

Table 2 illustrates a feedback template. The system uses a template to display feedback. The template is a method to turn competence elements into connected English feedback.

Table 2: Feedback template

Template Number	Feedback template
B	[capability verb] [subject matter] with achieved performance by [achieved performance] but required proficiency [proficiency level].
C	[capability verb] [subject matter] with achieved performance by [achieved performance] and within the range required proficiency [proficiency level].

If the achieved performance is within the range of the required proficiency, the system displays feedback based on template C. For the example, “execute automatically rowing with achieved performance by 23 strokes/minute and within the range required proficiency 22-24 strokes/minute using rowing ergometer machine.”

If the achieved performance is not within the range of the required proficiency, the system displays feedback based on template B. For the example, “execute automatically rowing with achieved performance by 18 strokes/minute but required proficiency 22-24 strokes/minute.

In case the target competence is not a leaf node, if the achieved proficiency is not within the required range, the system displays feedback as above and then traverses to the child node that has the same subject matter as the target node but with a lower capability level.

Experiment

The aim of the experiment was to explore athletes’ opinions on the pedagogical feedback generated by the competence model and the current feedback received through ‘Sean-Analysis’. It was expected that pedagogical feedback would be as acceptable to the athletes as their established feedback system. The experiment received Ethics Committee approval ES/10/02/002.

The predictor (independent) variable was feedback type, composed of two levels:

1. Sean-Analysis

Sean-Analysis (Session Management) feedback type was one of the current feedback systems for the rowing simulator. The system has been extensively used as a coaching and training tool (Rowperfect, 2006). It is able to accurately reproduce the physics of rowing and also generates feedback on the training session stroke-by-stroke.

2. PedaFeed

PedaFeed (Pedagogical Feedback) feedback type was the feedback system developed in this study.

The outcome (dependent) variable was athlete opinion. Such opinion corresponds to ‘reaction’, the first level of evaluation proposed by Kirkpatrick (1998). Kirkpatrick’s evaluation model has been considered to be the most useful framework in the evaluation of training (Falletta, 1998). In this study, the reaction focuses on the issue of how satisfied the athletes were with the feedback provided and how much they accepted the feedback type for the implementation of CBST.

The experimental participants answered a questionnaire comprised of eight items as follows, where each item was rated on a 5-point Likert scale.

- Item 1: I am able to identify and target the technique that I need to developed to reach my intended performance. This reaction was coded as ‘identify and target technique’.
- Item 2: The achieved performance verified that I had achieved my intended performance. This reaction was coded as ‘verified achievement of IP’.
- Item 3: I am able to track my capability level. This reaction was coded as ‘track capability level’.
- Item 4: The system allowed me to ensure that each technique is mastered. This reaction was coded as ‘ensured each technique is mastered’.
- Item 5: The system gave me adequate information on the set of techniques that build toward the intended performance. This reaction was coded as ‘adequate information’.
- Item 6: The system gave clear information on what I must be able to do before something else should be learned. This reaction was coded as ‘clear information’.

- Item 7: I am able to diagnose why I didn't reach my intended performance. This reaction was coded as 'diagnose failure of IP'.
- Item 8: The system encouraged self-regulated learning. This reaction was coded as 'encouraged self-regulated learning'.

Eight voluntary intermediate and expert rowers (n = 8) from the Itchen Imperial Rowing Club, Southampton, participated in the experiment. .

The experimental procedure divided into the following phases:

1. Introduction

Participants were informed of the general purpose of the experiment and its structure. Participants were also informed that they could drop out of the experiment at any time they wished.

2. Administration

Participants were asked to sign the informed consent form to confirm that their participation was voluntary.

3. Tasks

For the first task, half of the participants received Sean-Analysis feedback type and the other half received PedaFeed feedback type. For both types, participants were instructed to read a scenario description and interact with the feedback they were given based on a worksheet provided. Participants were instructed to raise their hands when they finished interacting with the system. Participants were also advised to work at their own pace and were not given any time limit. The participants were assisted if they had any difficulties with the worksheet.

For the second task, participants who received Sean-Analysis feedback during the first task received PedaFeed feedback type, and participants who received PedaFeed feedback type during the first task received Sean-Analysis feedback type. Participants were given the same instructions as above.

4. Questionnaire

After each task, each participant received the questionnaire described earlier. Participants were given as much time as they wanted to complete the questionnaire.

Overall, the whole experiment took about 60 minutes.

Results

The repeated-measures analysis was conducted using PASW Statistic 18®. For all analyses, missing values were ignored.

Table 3: Multivariate tests

Within Subjects Effect	The Statistic Method	Value	F	Hypothesis df	Error df	Sig.
Feedback Type	Pillai's trace	.875	1.000	7.000	1.000	.649
	Wilks lambda	.125	1.000	7.000	1.000	.649
	Hotelling's trace	7.000	1.000	7.000	1.000	.649
	Roy's largest root	7.000	1.000	7.000	1.000	.649

Table 3 shows multivariate tests of mean reaction ratings for feedback type. For these data, Pillai's trace (*p* = .649), Wilks' lambda (*p* = .649), Hotelling's trace (*p* = .649), and Roys's largest root (*p* = .649) do not reach significance (*p* > .05). The results show there was no significant difference on mean reaction ratings for feedback type, data taken together, F (7, 1) = 1.000, *p* > .05. Overall, mean reaction ratings for Sean-Analysis feedback type were not significantly different from the mean reaction ratings for pedagogical feedback type.

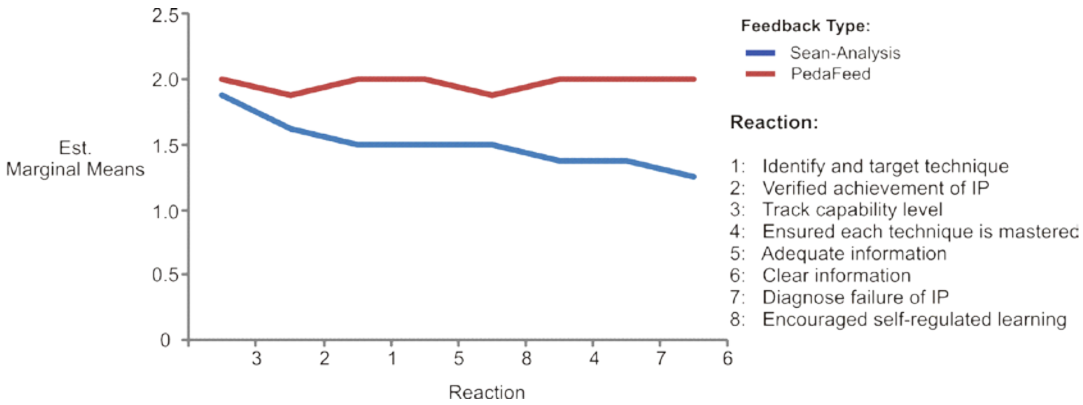

Figure 4: Profile plots of mean reaction ratings for feedback type

Figure 4 presents the differences on mean reaction ratings for Sean-Analysis feedback type and mean reaction ratings for pedagogical feedback type. Mean reaction ratings for pedagogical feedback type were all higher than those for Sean-Analysis, but based on Table 3, the differences were not significant.

Discussion and Conclusion

The results indicated that athletes were satisfied with the feedback generated from Sean-Analysis feedback and pedagogical feedback types. Both feedback types were acceptable in the athletes' training. This suggests that Sean-Analysis feedback type and pedagogical feedback type enable athletes to plot their progress and highlight areas of improvement. Both feedback types seemed able to generate feedback that was consistent with the athletes' intended training outcomes.

The pedagogical feedback of the system reported in this study, however, is both human readable and machine processable, supporting interoperability of the competence networks derived from the proposed framework. A competence statement which can be read, processed, and interpreted by machine contributes to the automatic generation of feedback, and offers a semantic structure for further processing.

A further major advantage of the pedagogical feedback is that it encourages self-regulated learning, supporting self-assessment and reflection in learning and allowing athletes to take more control of their training.

It is intended that future work with pedagogical feedback will: (1) provide feedback to coaches, allowing them to modify their training strategies, (2) use the competence network to improve the quality of recommended training, and (3) analyse the desired competences of athletes so as to recommend training materials. We believe the proposed approach assists athletes in finding a starting point and an efficient route through their desired competence network that will foster competence building.

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