Web Science: expanding the notion of Computer Science

Su White
Electronics and Computer Science
University of Southampton
UK
+44 23 8059 4471
saw@ecs.soton.ac.uk

Michalis N Vafopoulos
Aristotle University of Thessaloniki
Thessaloniki
Greece
+30 23 1038 3619
vaf@aegean.gr

ABSTRACT

The context of rapid external change presents particular problems to academic disciplines seeking to maintain timely, current and relevant teaching programs. Individual faculty may tune and update individual component courses while radical, strategic revisions are typically departmental-wide responses to perceived needs. Internationally, the ACM has defined curriculum recommendations since the 1960s and conducts a rolling program of revisions which demands much time and effort. Its 2005 overview volume identifies the range of the computing disciplines. Preparation for the Computing Curricula 2013 is underway, does web science have a place in the curriculum landscape? Web science was originally described as 'the science of decentralized information systems'. It is fundamentally interdisciplinary, encompassing the study of the technologies and engineering which constitute the Web, alongside emerging associated human, social and organizational practices. To date little teaching of web science is at the undergraduate level.

This paper discusses the role and place of web science in the context of the computing disciplines. It provides an account of work which has been established towards defining an initial curriculum for web science with plans for future developments utilizing novel methods to support and elaborate curriculum definition and review. The findings of a desk survey web science education is presented. Finally it recommends future activities which may help us determine whether we should expand the notion of computer science.

Categories and Subject Descriptors

K.3.2 [**Computers and Education**]: Computer and Information Science Education – *Computer Science Education, Curriculum.*

General Terms

Documentation, Design, Human Factors, Standardization.

Keywords

Co-creation, Co-evolution, Computing Curriculum, Educational Repository, Inter-disciplinarity, Negotiated Curriculum, Web Science Curriculum, Web Science Education.

1. INTRODUCTION

This paper considers what place web science might occupy within the family of computing disciplines. Initially defined as "the science of decentralized information systems", the coherent case for web science as a discipline came in 2006 [7, 8]. Having established itself as a rapidly evolving and fundamentally interdisciplinary [13, 20] discussions of the relationship between web science and computer science have begun [14, 17, 21].

Since 2006 a series of curriculum development workshops have taken place and a number of institutions have begun to teach web science at masters and undergraduate level. Postgraduate Summer Schools have been organized and seminar series established. Perspectives and understandings of web science have also found their way into existing courses by way of demonstrating current theoretical advances and furnishing examples of contemporary practice. A web science curriculum categorization exercise has been undertaken [24, 25] (Table 1) and collaborations have been formed to define and agree a web science curriculum [26].

Established computing disciplines have defined and now evolve subject definitions as formal recommendations on model curriculum. Typically published by professional bodies like the ACM, these provide definitions of the aims and objectives of curricula. Content is influenced by reflections, public discussion, and the de-facto realization of programs of study across universities and colleges worldwide. Faculty regularly report insights to communities like SIGCSE on changes whose impact ranges across individual topic areas, whole courses and programs.

Questions arise: does web science, as Shneiderman claims [21], signal a whole new way of thinking about computer science? Does web science have any chance of being recognized when as Hendler et al. point out [14], its only place in the ACM taxonomy is under *'miscellaneous'*? Can we find a place for web science in existing curricula, either as a specialism or in in its own right? Is it time to expand our notions of computer science?

This rest of this paper tracks the emergence of web science. It considers the background to recent changes in the ACM curriculum family. It presents an account on preliminary definition of the web science body of knowledge and associated curriculum initiatives. It compares the emerging web science curricula with the various computing curricula to provide evidence to take this discussion further.

2. BACKGROUND

Web science incorporates the quest to build an organized body of knowledge which can help make sense of the Web in an increasingly connected world. It is the study of an engineered technology and the inter-related impacts on human, social and organizational domains. The study of web science is fundamentally interdisciplinary since it incorporates enquiring into what constitutes the web, alongside how and why practices and organizations have emerged from, or are modified by, the wider interaction of society with the web. As Berners-Lee et al point out [8], like computer science, web science is partly analytic

Conference'10, Month 1–2, 2010, City, State, Country.

but also synthetic. However, we observe that web scientists practice in many different established disciplines. Some have originated in the computing disciplines others are found in independent disciplines utilizing their computing-related insights, expertise or perspective as core part of their subject specialism.

The extent of web science is discussed in section 2.3, however it should be emphasized that web science is more than the study of web technologies. The web ecosystem in its own right forms an important and coherent area of study. Web science is of particular interest to members of the computing disciplines because it is in many ways like information science; it brings together science, technology and engineering with social, human and organizational sciences. The remainder of this section compares the development of the current ACM curriculum family with the emergence the web science field of study and associated developments towards establishing an agreed web science Curriculum. It examines example programs and courses, and identifies current views on the broader issues of curriculum definition.

2.1 Web Science options

Currently the majority of formal web science teaching is at postgraduate level. Only a few undergraduate programs exist; more are emerging. Web science courses are however sometimes offered as electives or as additional specialisms outside the mainstream curriculum. Details can be tracked via the Web Science Trust (http://webscience.org/study.html), although a full current picture cannot be guaranteed. Furthermore many teachers are already integrating web science perspectives into the established software engineering, computer science, information technology and information science curriculum as they incorporate current examples and emerging ideas. Students too, at postgraduate and undergraduate level, can introduce web science into their studies by choosing project and dissertation topics which inevitably stray into the web science arena.

2.2 The ACM Curriculum Family

The continued evolving nature of the computing disciplines is widely acknowledged. External change triggers educational and curricula responses. Occasionally, when the disjunction becomes large, a wholesale revision is undertaken such as the recent changes at Stanford which Sahami et al. report in their 2010 paper [18]. The SIGCSE community provides a forum for sharing innovations, consolidating learning across our community of practice and providing additional communication channels between faculty and professional bodies.

The ACM has established a systematic program which draws on expertise from across the community and works to consolidate the learning into a coherent form manifested as formal models of various different recommended curricula [1, 2, 12, 15, 22]. Preparation for the Computing Curricula 2013 is now underway [19] which it is intended will build on previous model curricula [2, 3]. The rolling program of revisions demands time and effort, but it is a necessary response to the reality of our discipline areas. The nature of this overhead was emphasized in 2011 when the ACM/IEEE Task Force reported to SIGCSE “The development of curricular guidelines in computer science is particularly challenging given the rapid evolution and expansion of the field. Moreover, the growing diversity of topics in computer science and the integration of computing with other disciplines create additional challenges and opportunities in defining computing curricula” [19]

The ACM has sought to define curriculum recommendations since the 1960s and recognizes the diversity of computing disciplines with its 2005 overview volume [1]. It establishes its rationale in its opening words: “Computing has dramatically influenced progress in science, engineering, business, and many other areas of human endeavor. In today’s world, nearly everyone needs to use computers, and many will want to study computing in some form”. It identifies a family of disciplines which may grow or change in time (figure 1). CC2005 anticipates that other curriculum volumes would be needed for emerging disciplines.

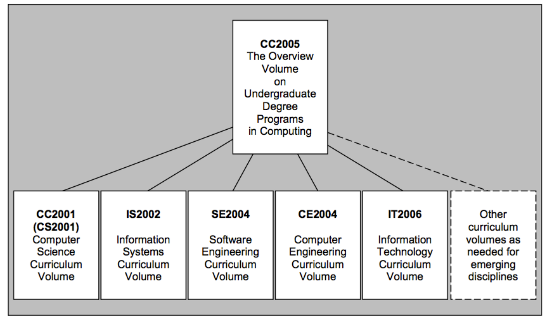

Figure 1. CC2005: the family of computing disciplines [1]

2.3 What is Web Science?

Web Science as a coherent area of study was brought formally to academic and public attention in 2006 with publications [7, 8] and the official launch of the Web Science Research Initiative. Today the formal web science agenda is driven through the Web Science Trust. The study of web science in fundamentally interdisciplinary since it incorporates the exploration of the technologies and engineering which constitute the web, as well as the human and social practices and organizations which have emerged from, or are modified by the wider interaction of society with the web. Studies across the various specialist components followed its emergence in the 1990s.

Hendler et al. in their 2008 CACM paper ‘Web Science an Interdisciplinary Approach’ opened the discussion on the place of web science in relationship to computer science [14]. They point out that the constraints of the ACM taxonomy reduces web scientists who research and publish in the computing disciplines to categorizing their work as *‘miscellaneous’*. They point out this is despite the fact that the Web is: “the most used and one of the most transformative applications in the history of computing, even of human communications. It has changed how those in academia teach, communicate, publish, and do research. In industry, it has not only created an entire sector (or, arguably, multiple sectors) but affected the communications and delivery of services across the entire industrial spectrum. In government, it has changed not only the nature of how governments communicate with their citizens but also how these populations communicate”.

The complexity and inter-disciplinarity of web science has been represented by Berners-Lee as a process in which social and engineering factors are both present [5, 8] This was first described by Berners-Lee et al and then subsequently developed into graphical form. The inter-disciplinarity of web science has been the subject of ongoing discussion [13, 14, 20]. It is manifested in the range of perspectives presented in papers at the web science conference, and in the variety of different viewpoints and specialisms which are observed in the various web science programs of study which are underway and represented at the annual web science curriculum workshop. Embracing inter-disciplinarity presents particular problems for course designers which will be discussed in greater detail in some of the remaining parts of this section.

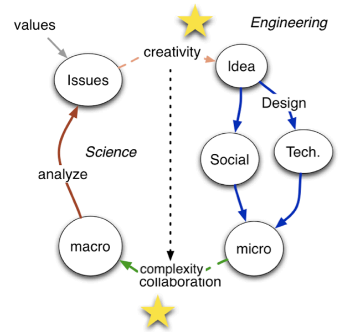

Figure 2. Berners-Lee's science and engineering approach with magic [5] modified to show complexity and collaboration

2.3.1 *Towards a Web Science Curriculum defined*

Since its inception, the Web Science Research Initiative and subsequently the Web Science Trust have convened annual workshops to discuss the contents and definition of the web science Curriculum. Institutions who have been early in developing and offering programs of study in web science have pooled their expertise. One outcome has been the definition of a web science subject categorization (WSSC). This work in progress is hosted on the Web Science Trust wiki (http://webscience.org/2010/wssc.html). The categorization can be applied to academic publications in web science, but a core part can also be used to define the boundaries of the web science body of knowledge. Thus it is of particular use as a step towards curriculum definition. Working predominantly from existing definitions used by the W3C and Web Science Conferences a team of collaborators led by Michalis Vafopoulos created a framework for web science subject categorization [24, 25]. The definitions are linked to matching categories in computing, mathematics, economics sociology and political sciences. An abridged version is able at the end of this paper.

Readers reviewing the subject categorization will recognize topics which also belonging within the curriculum of their specialist area. They may equate to whole courses or form part of the contemporary understanding of the specialism. However it is also clear that the topics are all part of an individual whole which incorporates the particular multi-disciplinary and inter-disciplinary perspectives which are essential to web science. The model of the Web which underpins the WSSC is an application that runs on the Internet and the progress of the latter is crucial to the Web's universal role. It is vital for innovation that the Internet and the Web work together but advance independently [6].

Category (A) categorizes publications concerned with instructional and research exposition, conference proceedings and collections of papers. It is not directly relevant to the teaching body of knowledge – although teaching and research methods do have a role; see Section 4. The web history and methodology category (B) includes web history, related biographies and epistemological and theoretical models of the web as an artifact. The Web Technologies (C) category addresses the underlying infrastructure (web milieux and basic web architecture) and the major enabling technologies for each Web era, namely Web 2.0, Semantic Web/Linked Data and Web of Things. Much of the debate within the web science curriculum community has focused on understanding the differences between a technologically-led perspective and a more interdisciplinary unified approach which is claimed for web science. Another area of contemporary interest concerns the class of scale-free networks, massively analyzed and used in various disciplines and applications during the last five years, was initially discovered in Internet and Web networks of real data [4]. The web analysis category (D) covers the mathematical methods applied in analyzing and exploring the Web. The web society category (E) covers topics which represent a range of human, social and organizational science perspectives: economic and business analysis; social engagement and social science; personal engagement and psychology; philosophy; law and politics and governance. This category reflects currently dominant associated specialisms and will inevitably change and evolve. It is also the area which institutions will use most selectively reflecting the expertise of institutions and faculty who are hosting and leading specific teaching programs. Like computer science teachers, web science teachers are developing expertise and understandings about effective ways in which to communicate the nuances of the discipline to learners. Particularly in seeking to explain the ways in which web science is distinctive from the study of web technologies. Teaching the Web, category (F) covers knowledge related to educational approaches for web science at pre-college, undergraduate and graduate levels.

2.3.2 *Web Science Teaching Today*

Although not exhaustive, the Web Science Trust maintains a list of taught programs demonstrating different ways in which web science can be nuanced (http://webscience.org/study.html). Listed programs at undergraduate and masters level are run Europe and the United States, although it is known that universities in Brazil, Pakistan, Korea and China are also actively teaching web science. Undergraduate programs are typically hosted in institutions where a number of faculty have established research in web science and there also exists an established stream of post graduate research students in the area. In order to extend and refine our understanding of the extent and nature of web science education, a brief survey (https://www.isurvey.soton.ac.uk/2290) has been conducted where respondents rate teaching practices against the WSSC. For the purposes of the survey, categories A (general) and F (teaching) were excluded although it is recognized that both are relevant to broader discussions of the curriculum. Interim analysis of the responses to the survey were reported to the 2011 web science conference [26]. The survey used the WSSC (Table 1) as a starting point for the body of knowledge. Responses largely confirmed a good match with interests and concerns of established teaching programs. Inevitably linguistic differences mean that detail of such understanding is best agreed via face-to-face conversations such as workshop and committee discussions. Since that time the number of respondents has increased, and the findings have remained broadly consistent. We will continue to gather this data from different communities worldwide, adjusting questions slightly to reflect particular understandings or teaching approaches which predominate in different education systems.

2.3.3 *An example of a Web Science Program*

Figure 3 shows an example structure of a web science masters program taught in Southampton. The program is taught to a cohort (~30) with a broad range of prior experience across science, technology and the human and social sciences, around 25% are CS graduates. UK students specialize from their first year of undergraduate study. The program has attracted approximately 50 female students (compared to around 10% in CS). The educational approach reflects the view that the web is a technical engineered artifact which is co-created and co-evolves. The course is highly participative using the students' prior experience as a resource to enable each participant to develop their own but shared understanding of the interdisciplinary nature of the web. The program shown has been developed over two years, and is now teaching its third cohort. The team who designed the course purposefully included web scientists who are not computer scientists and there here is active input from an industrial advisory panel. Content has been revised, reorganized and restructured in light of feedback from increasingly multidisciplinary cohorts of students. Although presented as a progression, apart from the capstone experience all components of the program are present as threads running through the taught sessions delivered over two consecutive semesters.

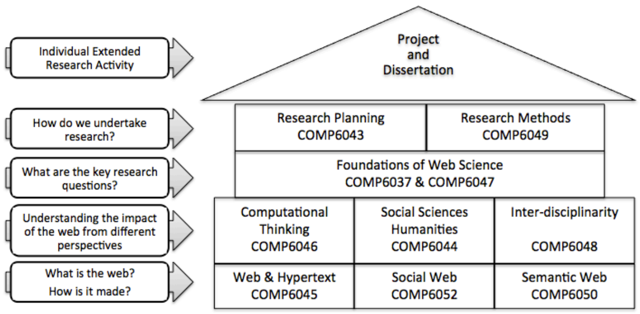

Figure 3 Explaining a course's content and approach

The diagram incorporates an acknowledgement of the need for interdisciplinary underpinnings to themselves support the foundations of web science. Research methods are emphasized for a number of reasons. 1) Web scientists work at the frontiers of knowledge and understanding so research skills are relevant to every possible outcome in terms of career progression. 2) It ensures that the teaching moves beyond the simple descriptive and theoretical, enabling the students to experience inter-disciplinarity rather than encountering it as a static concept. 3) Research activities provide an authentic vehicle of the critical and analytical thinking, communication, interpersonal and team skills.

The masters attracts a mix of home and international students. We offer Web Science and Web Technology (see diagram at webscience.ecs.soton.ac.uk). The web technology program takes a strong technological/software engineering approach, and only one module (Hypertext and Web Technologies for Masters) is common across the two programs. International students mostly opt for web technology (which is known and understood in their home countries) rather than web science – although, ambitious students who want to progress to PhD often choose web science. We are currently discussing and planning an undergraduate degree in web science but would not anticipate it differing radically from this basic structure. Of course there are differences between US and European educational systems which might affect such implementations. Currently our students are progressing to PhD studentships, but our industrial panel has a impressively wide range of companies represented, suggesting that future work destinations will incorporate specialist consultancies alongside names familiar from the stock exchange and technology press.

2.4 Web Science vs. Computing Curriculum

Little previous work exists discussing the role of web science in the computing curriculum. Riera's 2009 paper to the web science conference in 2009 argues for web science to be added to the family of computer-related curriculum [17]. Riera presents four distinct focus area though which the computing curricula has progressed, each of which persists today; the computer systems; computer networks; web technologies and 'webiety' i.e. web[soc]iety. The paper argues that each member of the family of computing disciplines occupied a different space across these focus area, and web science should occupy the next space.

3. WEB SCIENCE IN THE CURRICULUM

A review of computing curriculum 2005 and specialist curricula within the computing family was undertaken. CC2005 provided the starting point. Subsequently specific model curricula were examined (figure 1), computer engineering and software engineering models, deemed most distant from web science, were excluded leaving computer science[2], information technology [15]and information science [12, 22]. The comparison items were course areas, topics and specific bodies of knowledge.

Examining the computing problem space in CC2005, p16 [1] confirmed that web science could have a place in the family. Topic areas for the computing family are identified as Organizational Issues and Information Spaces; Applications Technologies; Software Methods and Technologies; Systems Infrastructure; and Computer Hardware and Architecture. Of the 17 specific relevant non-computing topics identified in CC2005, 12 were deemed to also be part of web science, overlapping directly with IT and IS. When considering computing topics the pattern was repeated, of the 40 potential topics, 37 were deemed relevant to web science, again consistent with IT and IS.

Next, specific model curricula all published at later dates, were examined.

- In IT2006 nine of the 13 Body of Knowledge (BOK) items map to web science, of the remainder there is some overlap (equivalent to approximately 75% of the suggested hours).
- In CS2008 looking at the core, only three of the 14 areas had near complete overlap, however many of the others are to be found in parts in the WSSC.
- In IS2010 four of the seven topic areas in Information Systems Specific knowledge were deemed relevant to web science, with overlap in the remaining areas. All of the computer areas identified were consistent with web science.
- MSIS2006 looked at masters degrees. It defined constituent courses rather than a body of knowledge. All of the courses had overlap with web science, but the focus was different, suggesting, like IT an overlap of more than 50%

New concepts introduced into MSIS2006 (business processes; emerging technologies; globalization; human computer interactions; and the impacts of digitization) were all considered relevant to web science. Similarly all items in the list of recent advances itemized by IT2008 were considered to be at the core of web science. Besides the overlap, there is a large part of the WSSC which is not found in any of the computing family curricula.

4. WHAT NEXT?

An initial examination suggests that web science may have a place in the family of computing disciplines. Current practice shows far postgraduate specialisms in web science than undergraduate. We might expect the specification of a model curriculum for web science to follow the pattern established by information systems in their recent recommendations [12, 22], but we might usefully debate whether web science is an undergraduate topic. Web science also impacts on the overall computing curriculum. The claims for web science add further complexity to discussions on the place of computational thinking introduced by Wing in 2006 [27]. Web science definition also make clear the need to differentiate between the science of the web, and the underlying methods tools and technologies so often manifested as components of the computer science and IT curricula. Web science covers much ground that is beyond the traditional focus of computing disciplines, which have implications for teaching and curriculum. This inter-disciplinarity of web science raises issues of the relationship between epistemological paradigms, cognitive approaches, and practical application first noted by Biglan [9]. The contribution by Halford et al. helps set out some of these challenges [15]. This is particularly relevant to the CC2005 listed 'performance capabilities of graduates'. Web science graduates would expect to perform more strongly in Biglan's soft applied area – suggesting a need to nuance the theory versus application differentiation used in the CC2005 problem space definition.

The sustained emergence of new methods and tools, never mind the interdisciplinary science of the web also challenge the traditional methods with which we define and publish model curricula. Community approaches to curriculum development already exists; in computer science CITIDEL is a repository of existing syllabi (http://www.citidel.org/) that enables designers of new courses to understand how others have approached the problem [23]. A community wiki was used in IS (http://blogsandwikis.bentley.edu/iscurriculum/) to help develop the curriculum dynamically [22] .

A detailed account of a project to dynamically create and establish a Web science curriculum were presented to the Web Science conference in 2011 [26]. The Web Science Curriculum Development project proposes a bottom up approach to drive curriculum definition, using the actual teaching materials collected in a community repository as the basis to iteratively negotiate and refine the definition of the curriculum. This is consistent with work by Cassells et al. Using a computing ontology for the foundation for curriculum development [10]. Reservations voiced by Mitchel and Lutter [16] are to some extent answered by the findings of Dicheva and Dichev which argue for the strength of the approach repository-led approach. [11].

5. CONCLUSIONS AND FUTURE WORK

Clearly more work needs to be done to agree whether web science has a place in the computing family and at what level. The approach of the web science curriculum development project may prove to be an effective means to do the groundwork in co-creating and defining the body of knowledge, and of identifying the actual focus of real courses. That body of knowledge will be more detailed when we have more courses, more students and larger cohorts.

But is web science special? There are many emerging, perhaps transient specialisms or sub-fields for example forensic computing or cybersecurity which may be historical artifacts which are able to capture the imagination of potential students. We believe Web science has a particular role in preparing graduates for jobs which do not yet exist. Although we may not be able to predict future job titles, we might predict that understanding the science of the web could be a crucial for employees and researchers of the future. Familiarity with a discipline which continues to emerge new technological solutions, business models and to augment and evolve human and social interactions can enable graduates to have the capacity to respond to future change. Developing the knowledge, skills and understandings which are concomitant with web science will be a powerful personal resource. Ongoing debate needs to be scheduled and we should seriously consider expanding our notions of computer science

6. ACKNOWLEDGMENTS

Special thanks to Hugh Davis, and all fellow participants in the Web Science Curriculum Development Project, and to all past participants in the web science curriculum workshops. Thanks too to Frank McCown for feedback on the draft. Michalis Vafopoulos received assistance developing WSSC from Ioannis Antoniou and Anastasia Dimou, Aristotle University of Thessaloniki, George Metakides, University of Patras, Leslie Carr, University of Southampton, Jacek Kopecky, The Open University and Kieron O'Hara, Web Science Trust, UK

7. REFERENCES

[1] ACM/AIS/IEEE-CS Joint Task Force for Computing Curricula. 2005. *Computing Curricula 2005: The Overview Report*.

[2] ACM/IEEE-CS Joint Interim Review Task Force. 2008. *Computer Science Curriculum 2008: An Interim Revision of CS 2001, Report from the Interim Review Task Force*.

[3] ACM/IEEE-CS Joint Task Force on Computing Curricula. 2001. *Computing Curricula 2001: Computer Science*.

[4] Barabási, A.-L. and Albert, R. October 15, 1999 1999. Emergence of Scaling in Random Networks. *Science*, 286 (5439), 509-512.

[5] Berners-Lee, T. 8-12 May 2007 The Process of Designing Things in a Very Large Space: Keynote Presentation http://www.W3.org/2007/Talks/0509-www-Keynote-Tbl/. *In Proceedings of the WWW2007*, (Banff, Alberta, Canada).

[6] Berners-Lee, T. 2010. Long Live the Web: A Call for Continued Open Standards and Neutrality. *Scientific American*, November 22 2010.

[7] Berners-Lee, T., Hall, W., Hendler, J., Shadbolt, N. and Weitzner, D. J. 11 August 2006. Creating a Science of the Web. *Science*, 313 (5788), 769 - 771.

[8] Berners-Lee, T., Hall, W., Hendler, J. A., O'Hara, K., Shadbolt, N. and Weitzner, D. J. 2006. A Framework for Web Science. *Foundations and Trends® in Web Science*, 1 (1), 1:130.

[9] Biglan, A. 1973. Relationships between Subject Matter Characteristics and the Structure and Output of University Departments. *Journal of Applied Psychology*, 57 (3), 204–213.

[10] Cassel, L. N., Davies, G., LeBlanc, R., Snyder, L. and Topi, H. June 23-27 2008. Using a Computing Ontology as a Foundation for Curriculum Development. *In Proceedings of the SW-EL'08 Sixth International Workshop on Ontologies and Semantic Web for E-Learning in conjunction with ITS 2008* (Montreal, Canada).

[11] Dicheva, D. and Dichev, C. August 31-September 3 2010. Finding Resources and Collaborators within Digital Collections. *In Proceedings of the International Conference on Web Intelligence and Intelligent Agent Technology*, (Toronto, Canada.).

[12] Gorgone, J. T., Gray, P., Stohr, E. A., Valacich, J. S. and Wigand, R. T. 2006. MSIS 2006: Model Curriculum and Guidelines for Graduate Degree Programs in Information Systems. *SIGCSE Bulletin*, 38 (2), 121-196.

[13] Halford, S., Pope, C. and Carr, L. April 26-27th, 2010, 2010. A Manifesto for Web Science? . *In Proceedings of the WebSci10: Extending the Frontiers of Society On-Line*, (Raleigh, NC: US.).

[14] Hendler, J., Shadbolt, N., Hall, W., Berners-Lee, T. and Weitzner, D. 2008. Web Science: An Interdisciplinary Approach to Understanding the Web. *Communications of the ACM*, 51 (7), 60-69.

[15] Lunt, B. M., Ekstrom, J. J., Gorka, S., Hislop, G., Kamali, R., Lawson, E., LeBlanc, R., Miller, J. and Reichgelt, H. 2008. *Information Technology 2008: Curriculum Guidelines for*

Undergraduate Degree Programs in Information Technology.

[16] Mitchell, S. M. and Lutters, W. G. 2006. Assessing the Value of Computer Science Course Material Repositories. *In Proceedings of the The19th Conference on Software Engineering Education and Training Workshops*

[17] Riera, D. 2009. Web Science: A New Computer-Related Curriculum. *In Proceedings of the WebSci'09: Society On-Line*, (Athens, Greece).

[18] Sahami, M., Aiken, A. and Zelenski, J. 2010. Expanding the Frontiers of Computer Science: Designing a Curriculum to Reflect a Diverse Field. *In Proceedings of the 41st ACM technical symposium on Computer Science Education*, (Milwaukee, Wisconsin, USA),47-51.

[19] Sahami, M., Guzdial, M., McGettrick, A. and Roach, S. 2011. Setting the Stage for Computing Curricula 2013: Computer Science -- Report from the ACM/IEEE-CS Joint Task Force. *In Proceedings of the 42nd ACM Technical Symposium on Computer science education*, (Dallas, TX).

[20] Shadbolt, N. and Berners-Lee, T. 2008. Web Science Emerges. *Scientific American*, 299 (4), 76.

[21] Shneiderman, B. 2007. Web Science: A Provocative Invitation to Computer Science. *Communications of the ACM*, 50 (6), 25-27.

[22] Topi, H., Valacich, J. S., Wright, R. T., Kaiser, K., Jay F Nunamaker, J., Sipior, J. C. and Gert Jan de Vreede. 2010. *IS2010: Curriculum Guidelines for Undergraduate Degree Programs in Information Systems*

[23] Tungare, M., Yu, X., Cameron, W., Teng, G., Pérez-Quiñones, M. A., Cassel, L., Fan, W. and Edward A. Fox. March 07-11 2007. Towards a Syllabus Repository for Computer Science Courses. *In Proceedings of the 38th SIGCSE Technical Symposium on Computer Science Education*, (Covington, Kentucky, USA).

[24] Vafopoulos, M. Web Science Subject Categorization (WSSC) Web Science Trust http://webscience.org/2010/wssc.html

[25] Vafopoulos, M. May 16-18 2011. The Web Science Subject Categorization (WSSC). *In Proceedings of the ACM WebSci '11*, (Koblenz, Germany).

[26] White, S., Croitoru, M., Bazan, S., Cerri, S., Davis, H. C., Jonquet, C., Prini, G., Scharffe, F., Staab, S., Tiropanis, T. and Vafopoulos, M. May 16-18 2011. Negotiating the Web Science Curriculum Development through Shared Educational Artefacts. *In Proceedings of the ACM WebSci '11*, (Koblenz, Germany).

[27] Wing, J. M. 2006. Computational Thinking. *Communications of the ACM*, 49 (3), 33-35.

Table 1. An abridged representation of the Web Science Subject Categorization.

NB: The full version at http://webscience.org/2010/wssc.html also specifies level 3 headings

A	**General – *not concerned with course content***
B.	**Web History and Methodology**
B.1	General Web History and Methodology
B.2	Web History Web Forerunners; Biographies and related stories
B.3	Web Science Theory and Epistemology Two Magics of Web Science; Actor Network Theory
C.	**Web Technologies**
C.1	General Web Technologies
C.2	Web Milieux Document technologies; Hypertext technologies; Internet technologies; Mobile Web technologies; Grid and Cloud computing technologies
C.3	Basic Web Architecture HTTP and related technologies; URIs; HTML; XML; CSS and related technologies; Interfaces and Browsers; Servers Web Services
C.4	Web 2.0 technologies
C.5	Semantic Web/Linked Data Metadata; Knowledge Representation; Ontology Languages; Linked Data; Natural Language Processing; Provenance systems in the Web
C.6	Internet/Web of Things
D.	**Web Analysis**
D.1	General Web Analysis
D.2	Mathematical Methods of Web analysis Web data sampling and analytics; Logic and Inference in the Web; Statistical Inference in the Web; Statistical Analysis of the Web; Web as a Complex System; Graphs; Networks; Mathematical methods for describing Web services; Crawling; Indexing and Searching; Data Mining; Information Retrieval and Machine Learning; Other Algorithms for the Web
E.	**Web Society**
E.1a	Economics Goods in the Web; The Web economy; Antitrust Issues and Policies in the Web; Intellectual property and digital rights management; Web-based economic development
E.1b	Business E-commerce Business models in the Web; Advertising in the Web; sponsored search
E.2	Social Engagement and Social Science Social networks; Mass phenomena; Collective intelligence; Peer production; Globalization; Systems; Social structures and processes; Virtual communities, groups and identity; Social capital and power inequality in the Web; On-line lives, intergenerational differences; Mass media
E.3	Personal Engagement and Psychology System Psychology and Behavior; Child and adolescent psychiatry; Tele-working
E.4	Philosophy Philosophy of information; Objects; Reference and Cognition in the Web; Ethics in the Web
E.5	Law Intellectual Property in the Web; Digital Rights Management; Digital crime; Laws for Web access; Antitrust Law
E.6	Politics and Governance Political science; E-Government; E-Politics; E-Democracy; Policy and Regulation; Web Governance; Privacy; Trust; Security; Network neutrality; E-Inclusion
F	**F - Teaching the web – *not concerned with course content***