Ontology-based IT Pedagogical Knowledge Framework

Kum Leng Chin, Elizabeth Chang, Douglas Atkinson
School of Information Systems, Curtin Business School,
Curtin University of Technology, Perth, Western Australia

kl.chin@cbs.curtin.edu.au; Elizabeth.chang@cbs.curtin.edu.au;
doug.atkinson@cbs.curtin.edu.au

Kevin R. Parker
Information Systems, Idaho State University, USA

parkerkr@isu.edu

Abstract

Prospective students often have trouble differentiating between many computer-related programs of study such as computer science (CS), information systems (IS), information engineering (IE), software engineering (SE), information technology (IT), electronic commerce (EC), computer engineering (CE), etc. To compound the problem many institutions offer programs with similar names but with different content, or programs with different names but with similar content. The extensive overlap in course content in many computing-focused disciplines has even created confusion among academics. This paper first reviews relevant literature on the topic and then presents a high-level view of an Information Technology (IT) Pedagogical Knowledge framework from an ontological point of view.

Keywords: Information Systems, Computer Science, Ontology, IT Knowledge Framework

Introduction

Computer-related occupations have been among the fastest growing in the job market in the past few years, and the majority of the advertised positions require applicants with tertiary qualification in the relevant disciplines (Hettiarachchy & Kuipers, 2003). However, students seeking a career in a computer-related field are often confronted with choosing the right program of study amongst the many options that are offered. There are few guidelines to help students to distinguish between programs such as computer science, software engineering, information systems, and many others. Analogously, industry is uncertain which program produces graduates equipped with the right skill set and level of competency to meet their demand. In addition to this confusion, universities around the globe face the serious problem of how to ensure that computer-related courses stay aligned with rapidly changing technology.

This study proposes the development of a high-level IT (information technology) pedagogical knowledge base that will make it possible to clearly distinguish between computer-related programs of study. This knowledge base will identify each of the programs and at the same time capture the relationship that exists amongst them. The knowledge base shall contain knowledge from three different perspectives: student, academic, and industry. An ontological approach to the design and development of such a knowledge base ensures that the information therein remains current due to the evolutionary nature of the ontology. The term "IT" is used here in the border sense to represent an overarching umbrella of all computer-related disciplines, similar to the definition of IT as explained in a number of websites such as http://www.webopedia.com and http://en.wikipedia.org/wiki/Information_technology.

"Ontology" is the term used to refer to a conceptualisation of some domain of interest that may be used as a unifying framework to solve problems through agreement about shared conceptualisations. An ontology reduces conceptual and terminological confusion by providing a unifying framework within an organization or community of users. This defines semantics for the system and provides an extensible model that can later be refined. Such a model also makes possible semantic transformations between different contexts from different sites, a feature required by an IT Pedagogical Knowledge Framework.

This conceptual paper begins with the identification of the underlying issues that cause the confusion outlined above, followed by an overview of the relevant literature before proceeding to our proposal of a preliminary high-level ontological view of IT-related topics, subjects, and courses. As this is a report on research in progress, no research findings or results will be discussed in this paper.

Underlying Issues Related to IT based Curriculum

Issue 1: Multiple Stakeholders: Academics, Students, and Industry

The design and development of the IT-related curriculum should not be carried out in isolation. It should take into account its main stakeholders: academics, students, and industry.

Academics

Those tasked with developing an IT-related curriculum and delivering the course material are the most prominent stakeholders in curriculum design. In recent years, providers of IT-related courses have been faced with the paradoxical situation in which there has been an increasing demand from industry for skilled information workers as opposed to declining student interest in computing-related courses in higher education (McKenzie, 2006). This undoubtedly has significantly impacted IS academics' task of ensuring that a curriculum both teaches relevant IT/IS skills while remaining attractive to students.

Teaching objectives and teaching methods can also influence the design and development of curriculum. Teaching objectives are dictated not only by the instructor but in some cases by the department or institution as well. The research interests of department members may also impact curriculum, particularly in graduate programs.

Finally, curriculum decisions, or at least the delivery of various courses, may be affected by the teaching methods used by the various academics involved in the curriculum design process (Singh, O'Donoghue, & Worton, 2005). For example, some courses may be designated as appropriate for distance learning. Some courses may also be well suited for extensive use of multimedia techniques, making extensive use of audio, video, etc.

Students

Those whose knowledge and skill sets are shaped by a curriculum should also be regarded as significant stakeholders in curriculum design. Potential students as well as current undergraduate and graduate students are greatly impacted by curriculum content. Former students can also provide valuable input.

Many factors affect a student's choice of a particular course of study when starting their tertiary education. One of the main motivations for undergraduate students is selecting a major that offers the most likely prospect of finding a lucrative and/or satisfying job upon graduation (Hemingway & Gough, 2000). For those whose studies will provide qualifications for a particular job, course relevance can be critical. Most computer-related jobs require bachelor degrees (Hettiarachchy & Kuipers, 2003).

Some students may plan to continue their studies after obtaining their bachelor qualification. Graduate students sometimes select a particular program or university based on the research being performed there.

Finally, former students who have entered the workforce (or failed to do so) can provide valuable feedback about the effectiveness of curriculum content. Their feedback can assist in assessing the relevance of the curriculum and determining means of improvement.

Industry

The IT industry is the ultimate evaluator of any IT-related curriculum, and as such is a critical stakeholder in the curriculum design process. The IT industry requires certain skills that meet certain standards, and this must be considered in curriculum design so that the requirements can be met. As Cassel, Davis, and Kumar (2003) point out, the specification of competencies for graduates of any program must be sufficiently fine-grained so that they can be combined in various ways to describe different types and levels of qualifications. The British Computer Society (BCS, http://www.bcs.org) has established the Skills Framework for the Information Age (SFIA), which is the high-level UK government-backed competency framework describing the roles within IT and the skills needed to fulfill them. The Australian Computer Society (http://www.acs.org.au) recently signed an agreement with other peak industry bodies to promote a global information and communication technology professionalism standard (Foreshew, 2007).

The rapidly evolving nature of technology means that skills requirements change as well. Curriculum designers must be aware of these changes and must adapt courses of study accordingly. In addition, educators should also consider the local, national, or international employment markets to avoid limiting student marketability to a certain region. Student demographics can also have a significant impact on the matter. For example, courses with a high number of international students must consider the job markets these graduates are targeting upon graduation. IT-related curriculum must be updated frequently to accommodate all of these factors so as to ensure IT courses of study stay relevant.

Issue 2: Confusion between IS, IT, CS, CE, SE, EC, etc.

Many have difficulty distinguishing between IS, CS, CE, SE, and EC (Anthony, 2003; Cohen, 1999). While these IT-related fields may be closely related, the distinction between them is important as it may not only lead to different curriculum content but also to different teaching approaches and expected learning outcomes. Further, each of these disciplines may also lead to different job opportunities; hence this confusion could lead to students choosing the wrong course of study and thus the wrong career path.

Issue 3: Inconsistent Labelling

While many universities offer IT courses, a quick look at the description of those courses reveals that they may vary significantly from one university to another. As IT courses in many universities are not strictly governed by a particular accreditation body, individual institutions have greater freedom in designing their own curriculum. This has, however, created confusion among many academics and students. To further add to the confusion, disciplines like IS may be variously referred to as Business Information Systems, Computer Information Systems, and Management Information Systems (Hettiarachchy & Kuipers, 2003). It is therefore very difficult to compare courses across different institutions given the differences in names and/or curricula. This has made it difficult to standardize IT courses and also difficult for universities to benchmark against top universities when seeking world-class status, and to standardise the quality of teaching and learning.

Issue 4: Evaluation and Validation of IS Curriculum

In order to keep up with changes, many universities revise their IT curriculum frequently. Hence, it is desirable for the IT academic community to be able to share their knowledge in curriculum design and development in order to provide higher quality education. One way to evaluate the curriculum of a particular institution is to refer to existing documentation, such as that available at the institution's website. However, this process is not only tedious but also misleading, as information could be scattered, incomplete, and sometimes out-dated. There is a need for an approach that allows this information to be stored, retrieved, and shared amongst the IS academic community to enable the task of course comparison and evaluation across different institutions, to enable individual institutions to validate their own courses, and to integrate shared knowledge in course curriculum design.

Pertinent Literature

Literature shows that past attempts on setting standards were mainly through the development of model curricula. The Association for Computer Machinery (ACM, http://www.acm.org) in conjunction with the Association for Information Systems (AIS, http://home.aisnet.org/joomla/index.php) and the Association of Information Technology Professionals (AITP, http://www.aitp.org/index.jsp) recently updated their undergraduate and graduate IS model curricula: the IS 2002 Model Curriculum and Guidelines for Undergraduate Degree Programs in Information Systems (Gorgone et al., 2003) and the MSIS 2006 Model Curriculum and Guidelines for Graduate Degree Programs in Information Systems (Gorgone et al., 2006). These model curricula provide an architecture of the IS curricula and detailed descriptions of courses within each program.

The problem with the model curricula is that the sheer amount of conceptual information implicit in the stated course objectives is more than can be presented within a single course (Beachboard & Parker, 2005). Consequently, instructors face the challenge of determining how much of the content can be reasonably omitted. Given that some depth must be sacrificed to achieve the desired breadth of coverage identified in the model curriculum, the IS community needs a more complete specification of the baseline technical concepts and skills that graduating IS students should possess (Beachboard & Parker, 2005).

The ACM, AIS, and the IEEE Computer Society also produced Computing Curricula 2005 – The Overview Report (ACM, 2005) to describe the characteristics of the various undergraduate programs of computing-related disciplines in an attempt to identify the similarities and differences between these programs. These programs include CE, CS, IS, IT, SE, and others.

There is very little literature on defined terminology or standards shared between these disciplines. The ACM Computing Classification system (1998), a four-level hierarchy of terms with three coded levels and an un-coded level of subject descriptors, contains "Information Systems" as one of its first-level categories. Falkenberg et al. (1998), in their 1998 FRISCO report, made a similar attempt to define a subset of IS concepts. The report acknowledged that it is difficult to define a single unified vocabulary for the whole domain of information systems. FRISCO maintained that it did not intend to set standards because the terminology of a particular domain is based on a conceptual foundation, and such a foundation will only emerge as a result of consensus gradually reached by the professional community working in that domain (Falkenberg et al, 1998).

Cassel et al. (2005), in their Information Systems Curriculum project, endeavor to compile a comprehensive listing of all topics relevant to the computing and information discipline. Their project will be discussed further in a later section.

Ontological Approach to Knowledge Representation

An ontology is usually constructed for a specific purpose. The objectives of an ontology thus translate into a set of competency questions that in turn define what information the ontology should provide (Gruninger & Fox, 1994). Ontology-based applications can be categorized into these classifications: knowledge management, information retrieval, portal and web communities, and e-commerce (OntoWeb, 2002). Each of these classifications contains different requirements. The metadata of this ontological view of IT-related topics, subjects, and courses will be gathered from published materials and the three stakeholders: academic, students, and industry.

Model curricula such as IS 2002 (Gorgone et al., 2003) and MSIS 2006 (Gorgone et al., 2006) are useful specifications but they are also relatively static, with changes coming about as a result of periodic reviews that could be a number of years between iterations. In addition, apart from information on curriculum, there are other considerations that should be included in the knowledge base.

A computer-based, Internet-enabled knowledge base for IS education promises to be a more flexible and robust approach. In 2002, with funding from a number of accreditation organizations including ACM and IEEE, a project was initiated to produce an ontology for computing and information-related disciplines (Cassel et al., 2005; Davies, Cassel, & Topi, 2006). The main objectives of the project, as stated in Cassel et al. (2005) are to produce a representation of global information and computing disciplines and to show the interrelationships amongst topic areas. The product of the project is intended for a number of applications of varying nature, including institutions developing curriculum, accrediting bodies evaluating programs, employers seeking programs that offer specific skills, students identifying their strengths and areas for further development, and others. However, this work does not seek input from academics, industry, or students. Instead, the project is to be implemented using the Social Network Analysis (SNA) approach with the primary data source being the digital library. This work in still in progress and it may be some time before it is available for evaluation.

This research, based on previously cited studies and in line with the model curricula like IS 2002 (Gorgone et al., 2003) and MSIS 2006 (Gorgone et al., 2006), proposes to use ontological principles for the organization of IT pedagogical knowledge, as shown in Figure 1. This is an initial conceptualisation of IT-related curriculum and its relation to other IT pedagogical knowledge. As represented in Figure 1, IS curriculum is located at the top right corner of the Knowledge Hierarchy, with other disciplines providing a foundation. However, some IS professionals may take a more narrow view, considering IS to only cover the area designated by region A (near the top right corner).

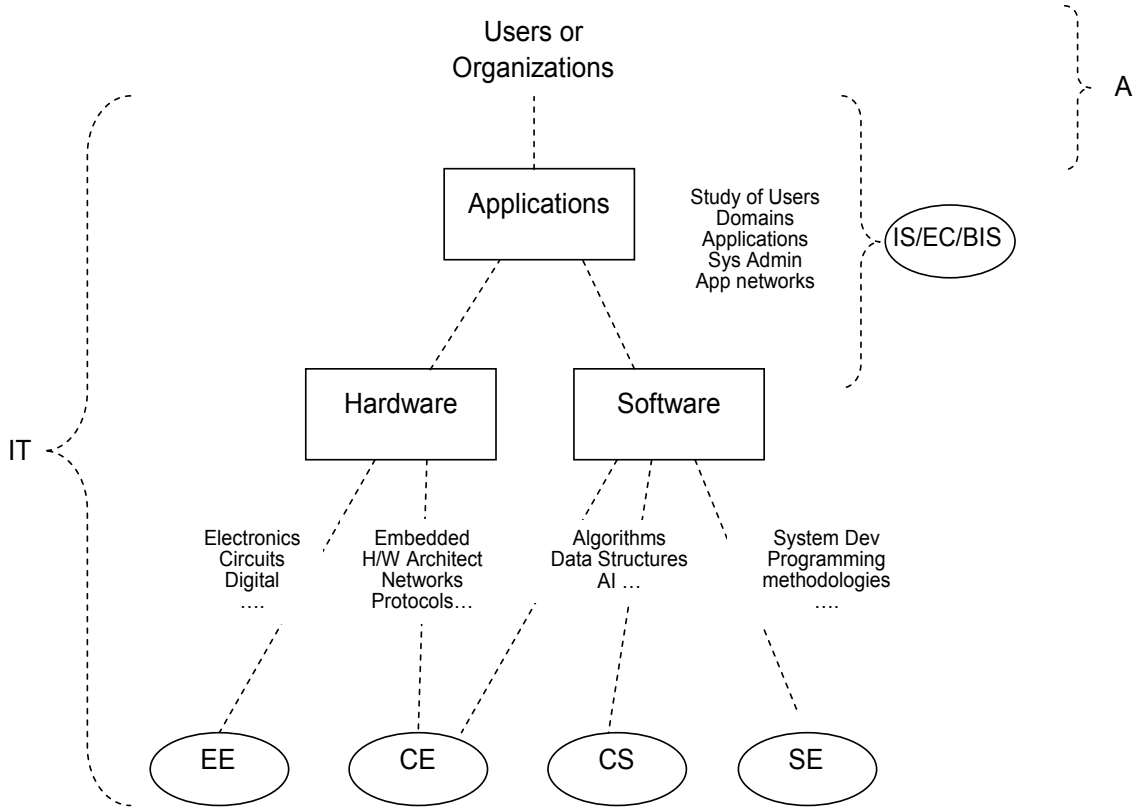

Figure 1: An Ontological view of IT pedagogical Knowledge Hierarchy

Note that Figure 1 represents IT as encompassing all computing-related fields. This is in line with the practical use of the term IT in industry, business, commerce, and government where IT refers to the computer systems (software, hardware or platforms) to support the organization and extend the organization's strategies and objectives (AS8015, 2005).

In general, a course may be developed through top-down or bottom-up approaches. (Note that in Australia, a "course" is equivalent to a "degree" in the USA.) Normally when a course is created, subjects within a course must be defined, followed by detailed topics within each subject. However, there are several problems that have to be considered, including:

(1) One subject may have different names across different universities, or the same name may be used for subjects having totally different topics,

(2) A subject may not cover all the topics that it should cover, or that equivalent subjects at other universities cover,

(3) A subject may not align with what industry requires.

Therefore, we propose a layered ontology view of a Pedagogical System that can be applied to any IT-related curriculum, starting at the concept level, then organized into subject level, and then finally into a course level, so that we produce a layered ontology as depicted in Figure 2.

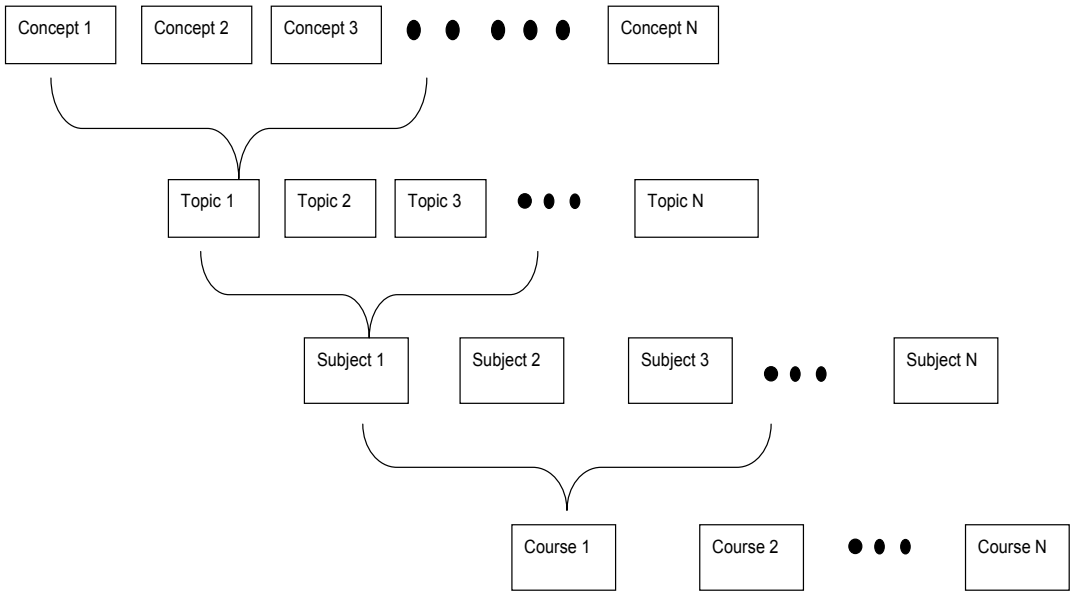

Figure 2: Layered Ontological representation of a Pedagogical System

Figure 2 shows that a curriculum is developed by carefully defining Concepts and grouping them into Topics. The grouping of Topics forms Subject areas, and grouping and sequencing Subjects leads to Courses. Detailed design of the set of properties of each element within the ontology will take into consideration the three main stakeholders–academics, students, and industry–in order to ensure that the ontology can satisfy queries from all three perspectives.

Mapping Competencies to Ontology Hierarchy

One of essential keys to quality education is to first define competencies. For example, what expectations does industry have for a software engineering professional, a computer science professional, or an information system professional? This study has adopted as a foundation the Skills Framework for the Information Age (SFIA), established by the British Computer Society (BCS). We model IT industry and other traditional industry-required competencies that tentatively contain: 1) Category & Subcategory, in which skills are grouped into categories and subcategories describing broad areas of work; 2) Level, which represents the degree of responsibility that an IT practitioner exercises, and 3) Skill, showing a recognisable area of IT competence within the workplace. Figure 3 demonstrates a conceptual view of the mapping between the competencies and ontological hierarchy of the IT- related Pedagogical System. We map between competencies at the concept level, topic level, subject level, or course level. This involves 1) grouping the knowledge at concept, topic, subject, and course level, taking note that the required knowledge may be satisfied by a combination of concepts or topics or subjects or even courses; 2) sequencing the concept, topic, and subject deliveries where each of these could be covered in various depth such as introductory, intermediate or advanced level; and 3) defining prerequisites between courses, subjects, topics, and concepts to ensure the integrity and quality of any curriculum based on the ontology.

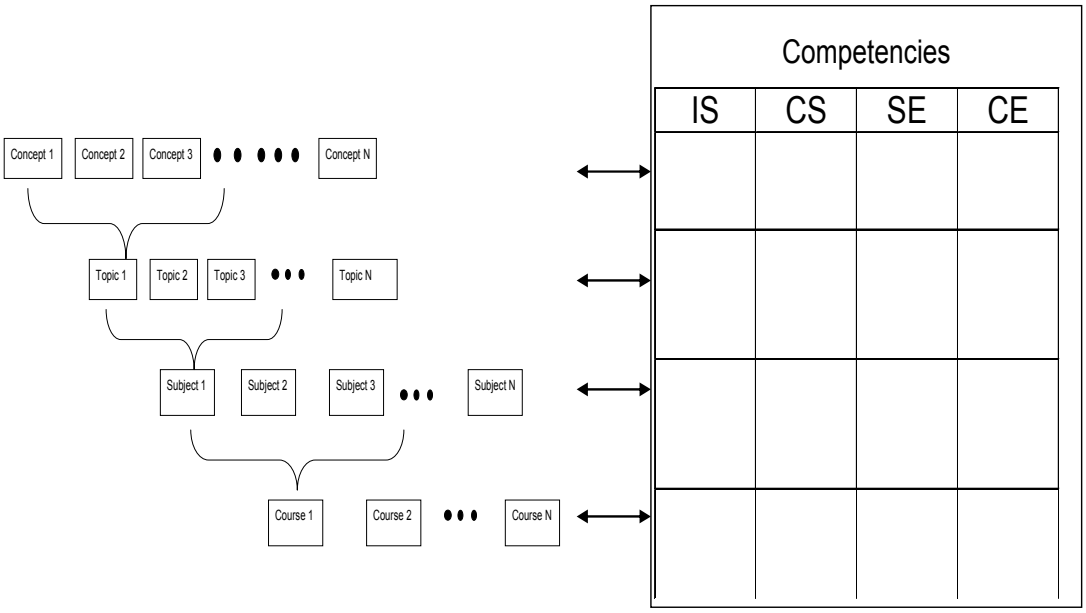

Figure 3: The Mapping between competencies and layered IT pedagogical knowledge organization

Competency involves broader issues, including technical issues, oral and physical presentation issues, feasibility studies, etc. For example, an IS professional must be capable of presenting a case explaining the need for and intricacies of the development of a particular system, and must also be capable of carrying out feasibility analysis and cost benefit analysis. This requires knowledge of several topics. One should be able to group such topics to identify a subject.

For some subjects the title is irrelevant; certain common topics always seem to be present. Therefore, the mapping of competencies and topic areas for these subjects is commonly accepted.

An Ontology View mechanism will be included to provide three levels of views of varying granularity: a conceptual level view that allows users to view at a high level abstraction by specifying a constraint of their view; a logical view that provides a view of a subset of the ontology (sub-ontology) from the IT Pedagogical Knowledge Framework; and a physical level view that allows educators to customize the sub-ontology to their specific educational needs.

Significance

This research is intended to help streamline the curriculum development process across IT fields of study, and the end product will result in knowledge being better defined, more clearly structured, and easier to access. The end result will enable easy access to IT pedagogy knowledge and hence will simplify the process involved in curriculum design and the development of IT-related courses.

Pedagogy is very important for quality teaching when it comes to course evaluation. Therefore the solution should not only facilitate the design and development of IT-related curricula, but should also facilitate the design of pedagogy in IT-related courses. As a tool for knowledge sharing, it is expected that the content of the ontology will be under heavier and more timely scrutiny by the IS/IT academic community, which could lead to more pedagogically sound curricula.

This study is intended to fill a void that currently exists. The resulting tool will facilitate knowledge sharing amongst the IS/IT academic community and assist in critical activities like curriculum development and redesign.

In addition, the resulting ontology can be used as a basis for applications designed to assist students in choosing the right course for a specific career path, as well as for the IT industry to gain insight into graduates' qualifications and their potential contribution in the industry.

Conclusion and Future Work

This research aims to develop an ontological approach for IT pedagogical knowledge organisation, i.e., an Ontology-based Knowledge Organisation Framework for Information Technology Pedagogy. It is also intended to facilitate the design and development of IT-related curriculum. In this paper, we have presented a preliminary view of an IT pedagogical knowledge framework. We are in the process of establishing commonly accepted standards and uniform IT concepts, topics, subjects, and courses along with terminology and concepts, with a clear relationship between concepts in the field of IT. We are also synthesizing commonly accepted competencies in the IT field, including IS, CS, CE, SE, EC etc., and developing a mapping between those competencies and ontological concepts, topics, subjects, and courses. The approach will then be validated against the IT industry in Australia and Asia by means of seeking verification and feedback from employers and IT graduates.

An evaluation model will be developed to assess the usefulness of the created ontological solution. The proof of concept through curriculum design will be provided as a means of evaluating the usefulness of the developed IT Ontological Knowledge Framework. Academics from various universities throughout Australia and overseas will be invited to participate in the evaluation process. Feedback from this process will be analysed and addressed in the study.

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Biographies

K L Chin is a lecturer at School of Information Systems, Curtin University of Technology. Chin's current research interest is in the area of IT-related curriculum and ontology applications. Chin has numerous publications in the area of teaching and learning, including cultural issues in teaching and learning and e-learning.

Professor Chang is a Professor in IT and Director of the Research Institute for Digital Ecosystems and Business Intelligence (DEBI Institute). She is also a Director for the Research Centre of Frontier Technologies for E-Enterprises at Curtin Business School. She has been awarded the Vice Chancellor's Outstanding Performance Award for 2005 and the Dean's Best Researcher of Year Award for 2005 and 2004. She has co-authored 3 books and has published over 350 scientific papers as book chapters, in international journals and at refereed conferences as well as numerous invited Keynote papers and Tutorials.

Dr Doug Atkinson is a Senior Lecturer in Information Systems at Curtin Business School. His research interests include ontology, knowledge management, collaborative systems, plagiarism detection software, generic graduate skills and information literacy. He has published in Interfaces, and the Australian Computer Journal.

Dr. Kevin R. Parker is a Professor of Computer Information Systems at Idaho State University, having previously held an academic appointment at Saint Louis University. He has taught both computer science and information systems courses over the course of his sixteen years in academia. Dr. Parker's research interests include competitive intelligence, knowledge management, the Semantic Web, and information assurance. He has published in such journals as *Journal of Information Technology Education*, *Journal of Information Systems Education*, and *Communications of the AIS*. Dr. Parker's teaching interests include web development technologies, programming languages, data structures, and database management systems. Dr. Parker holds a B.A. in Computer Science from the University of Texas at Austin (1982), an M.S. in Computer Science from Texas Tech University (1991), and a Ph.D. in Management Information Systems from Texas Tech University (1995).