

A Sustainable ICT Education Ontology

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Abstract— As Information and Communication Technology (ICT) plays an increasingly important role in businesses and all kinds of industry the demand for ICT skilled workers has also increased significantly. To meet this demand young people are encouraged to study ICT and choose ICT as a career. However, ICT does not appeal to many young people due to its poor image and many employers have criticized ICT courses being out dated and irrelevant. In this paper we propose an ontological solution to organize knowledge in the domain of ICT education. The proposed ICT Education Ontology (IEO) consists of four related sub-ontologies: ICT curriculum, ICT jobs, ICT skills and ICT research. The purpose of the IEO is to provide clear definition on terms and concepts used in these four related areas within the context of ICT education.

Keywords: Ontology; ICT Education; ICT Curriculum, ICT Skills, ICT Jobs, ICT Research

I. INTRODUCTION

Over the course of the past three decades, information and communication technologies (ICT) have become ubiquitous in our everyday life. ICT now plays an increasingly important role in the advancement and operations of many fields such as medical science, manufacturing, transport systems, government departments, the arts, entertainment, businesses of all sizes and shapes and many other sectors. In the aftermath of the recent global financial crisis, leaders from industry, government and civil society agreed that ICT can play a vital role in the pathway to an economic recovery [1]. With ICT being deployed and utilised in so many sectors to carry out a wide range of tasks, it is very important to ensure a sufficient supply of skilled ICT workers to meet the demand from workforce. It is therefore alarming to read from a number of recent reports on ICT skills shortage [2-4]. To maintain a continuing supply of skilled ICT workers there must be a steady number of young people wanting to study or to be trained in ICT related disciplines every year. However, figures from [5] show that the total number of eligible applicants applying to study ICT courses in Australian universities had dropped from 14,642 in 2001 to 5478 in 2009; although the number has been stabilised since 2006. There is therefore a sense of urgency in addressing this discrepancy, as pointed by ACS CEO Kim Denham [6], ICT skills are crucial to the health and survival of Australian business, and a potential mismatch between student demand for courses and the skills demanded by industry will undermine future economic opportunities.

There are many theories in why young people no longer wanting a career in ICT. One of them being ICT is perceived as not 'cool' enough for high school students [7]. Some students, on the other hand, reported that they lacked sufficient information about careers in ICT [8]. Consequently many students still tend to associate ICT with the more traditional information technology-related vocations such as

programmer or computer technician. This perception means that many students see ICT careers as 'boring', and associate them with 'being stuck in front of a [computer] screen all day' and lacking human interaction [8].

To attract students, ICT courses need to be interesting, relevant and up-to-date with the current technologies. However, feedback from ICT industry suggests that ICT curricula in schools and universities are dated and in need of radical change [9].

In this paper, we will first outline the underlying issues that may have contributed to the low student enrolment problem faced by ICT Education sectors. We then outline the purpose of the proposed ICT Education ontology, its main stakeholders and its main components: ICT Curriculum Ontology, ICT Job Ontology, ICT Skill Ontology and IT Research Ontology. The design of our proposed ontological solution aims to facilitate knowledge sharing amongst multiple stakeholders with the objectives of addressing those underlying issues.

II. ISSUES IN ICT EDUCATION

One way to combat the problem of ICT skills shortage is to encourage more young people to take up study and training in ICT. To achieve this we must first address some of the issues related to ICT education:

A. Changing the 'Image' of ICT Professionals

Many people have little or no knowledge about the jobs of ICT professionals. There are also misconceptions that ICT workers are nerds sitting in front of computers in dark rooms with no social life. This is hardly appealing to many young people. Providing up-to-date information on the many job roles of ICT professionals will not only rectify those misconceptions but also to inform young people the many exciting career choices within the ICT industry they can choose from.

B. ICT as a Discipline is not Well Defined

Unlike the more traditional academic disciplines such as law or medicine, many people are unsure about the outcomes of an ICT qualification. Even within the ICT discipline, the differences between various areas of study such as computer science, software engineering, information systems, etc., are not clearly defined. Furthermore, in recent time, many new ICT related courses have been created, with some being cross-disciplinary with other fields. As a result prospective students may be confused about what career an ICT degree in each of these areas of study will lead to. This confusion may put off students from choosing ICT as a major area of study when they enter universities.

C. Many ICT Courses are Perceived as out-dated or Irrelevant or both.

ICT is a fast evolving field where new technologies emerge every day. Students are often frustrated with out-dated

contents of the ICT courses they enrolled in. Students may also feel that what being taught in classes have little relevance of what actually happened in the real world and that the skills they acquired may not equipped them for employment upon graduation.

D. Lack input from the ICT industry

Many higher education institutes such as universities do not sufficiently engage the industries when designing or reviewing their ICT course curriculum. This lack of collaboration could result in the issue of ICT skill shortage not being addressed hence led to industries losing faith in ICT graduates meeting their skill needs.

III. ICT EDUCATION ONTOLOGY (IEO)

What is ontology? Ontology is a specification of a conceptualization [10]. It is an explicit formal specification of the terms in the domain and relations among them [10]. Noy and McGuinness [11] further explained that “An ontology defines a common vocabulary for researchers who need to share information in a domain”. There are a number of reasons why ontologies are being built but sharing common understanding of the structure of information among people or software agents is one of the more common goals in developing ontologies [10, 12]. And it is also the main reason behind our proposed ontological solution where we aim to define and organize knowledge in the field of ICT education.

The purpose of the ICT Education Ontology (IEO) is to provide a central repository of classified knowledge in ICT education. The field of ICT is expanding rapidly with new technologies and applications emerging in lighting pace. This brings about new terminologies, concepts, new usages and new skills. The applications of ICT are wide and varied, there are now plenty of career choices exist in the ICT field and many ICT job roles are highly professional and well paid. Somehow, we need to convey this information to young people if we are to entice them into considering ICT as a career. While most information are available on the Internet but as we know locating relevant and useful information amongst the vast ocean of information and sometimes misinformation on the Internet can prove to be very challenging. Moreover, information needs to be in the right context to be useful.

An ontology that captures all relevant information in one place can prove to be very efficient in information seeking. More importantly, ontology allows us to define concepts as well as relationship between items of concept rather than the piece meals obtain elsewhere. Ontologies are often designed with specific purposes in mind so knowledge within the ontology is structured in ways to fulfil those purposes.

The design of the proposed ICT Education Ontology (IEO) needs to take into consideration of the different perspectives of the key stakeholders. Noy and McGuinness [11] suggests that it is always a good idea to sketch out a list of questions in which the Ontology aims to answer to determine its scope. As our objective is to address those issues mentioned above, the design of our ontology shall aim to answer the following questions:

- What are the different ICT courses available? And how do they differ from each other?
- What skills do you learn from which ICT course?
- What jobs are available in the ICT field? What skills are required to do each of these jobs?

IV. KEY STAKEHOLDERS OF ICT EDUCATION

By examining the issues outlined in II above we can observe that:

- Students need to be better informed about what different ICT courses are available and what careers they can lead to
- Employers need to be informed about what skills and knowledge are taught in which ICT course
- ICT education providers need to know what ICT skills and knowledge are in demand so they can be incorporated into courses they teach
- “research feeds teaching” – if academics and industry collaborate more in ICT research projects then ICT courses will naturally be more relevant to industry practices

Clearly there are three key stakeholders to be identified here – student, ICT course provider and ICT industry (employer) and they have different needs to be met. These three main stakeholders are therefore the target users of the proposed ICT Education Ontology. Their requirements of IEO help shape the design of IEO and shall be discussed as follow:

A. Student

The term ‘student’ here is being used in a very broad sense which include current, past and future (potential) students who are interested in pursuing an education in ICT. Past students also include those who have already attained some form of academic qualification in ICT, i.e. graduate. They may also be seen as potential students who may return for further studies. Student will use the ICT Education Ontology to enquire about curriculum matter as well as looking up on ICT jobs and their required skills.

Students may use the IEO to seek answers to questions such as:

- what different kinds of ICT courses are available
- what are the differences amongst these courses what skills are taught in these courses
- which ICT course best suit my interest

B. ICT Education Provider

ICT Education Providers refer to academics teaching and/or researching in the ICT field, as well as those responsible for the management of ICT courses, e.g. universities. ICT Education Providers also involve in the design and revision of curriculum, and have the responsibility to ensure courses are up-to-date and relevant to industry practices. Academics contribute to research in the field but they should also aim at aligning curriculum with research as well as feeding research to teaching. Questions that ICT education providers will want to ask include:

- what ICT skills are in short supply
- where can new skills be incorporated

C. ICT industry/Employer

ICT industry incorporates organisations that provide hardware, software and people. It also includes the people and products developed through the application of communication and technology within other industries [13]. Employers of ICT industry employ ICT graduates. Employers define ICT jobs; specify what skills and knowledge are needed for each job. However, in order to get the right people for the right jobs, employers need to know about the contents of the various ICT courses to ensure their new recruits equip with the suitable skills and knowledge. Specifically employer asks question such as:

- Which ICT course produces the right graduate for this job?
- What skills and knowledge does a graduate of a specific ICT course possess

V. COMPONENTS OF ICT EDUCATION ONTOLOGY (IEO)

To serve the purposes of the multiple stakeholders, the ontology of ICT education must contain knowledge of curriculum, job, skills and research in the ICT field. Hence, IEO is made up by four separate but related ontologies (as depicts in Figure 1): Ontology of ICT curriculum, ontology of ICT Job, ontology of ICT Skill and ontology of ICT Research.

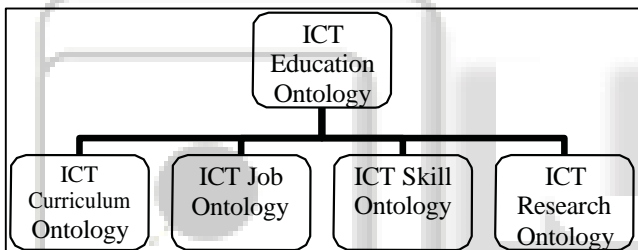


Fig. 1: Main components of ICT Education Ontology

A. ICT Curriculum Ontology

ICT curriculum ontology consists of a set of ICT concepts organised in a hierarchical structure (see Figure 2, 3). At the first level, these concepts are being categorised according to the different sub-disciplines in the field of ICT study, i.e. Computer Engineering, Computer Science, Software Engineering, Information Systems and Information Technology. Many ICT concepts may come under more than one of these disciplines and that will be reflected in the ontology.

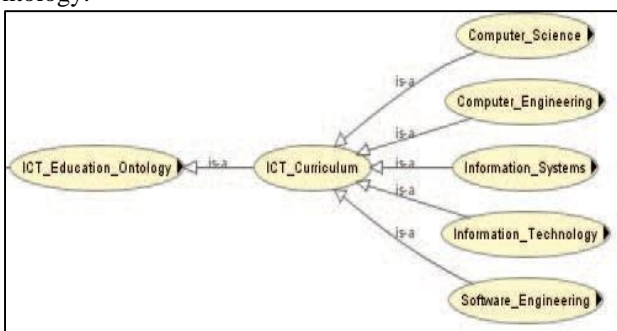


Fig. 2: Part of ICT Curriculum Ontology

Many ICT courses are being offered in these sub-disciplines; however, the contents of courses within each

discipline are not necessarily consistent. In some part of the world, accreditation bodies manage to standardise some curricula, others, however, bear significant differences despite the similarity in names or resemblance too much even when they are supposed to be in different sub-disciplines.

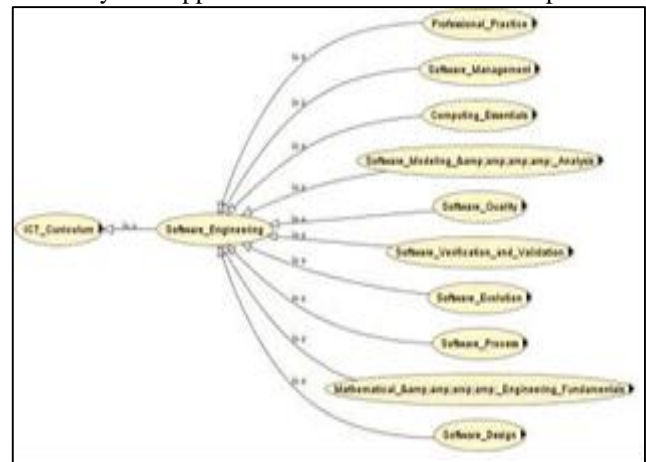


Fig. 3: Each Concept may be further broken into sub-concepts

In ICT curriculum ontology, a number of model curricula will be adopted to form a body of knowledge in ICT curriculum. These model curricula are designed and published by internationally recognised accreditation bodies such as ACM/IEEE, AIS, etc.

B. ICT Job Ontology

The types of ICT jobs available reflect the current job market in ICT industry. Some job titles evolve significantly over the years; many new titles have emerged in recent years, the position CIO, for example, did not exist ten years ago. Similarly, many job titles disappear over the year; EDP officer is one of them for example. Figure 4 shows part of the ICT Job ontology with a number of ICT job categories. Each of these categories will be further refined into job positions where each will be defined with title, position description, essential skills, etc.

There are four main reasons to include ICT job as a main component in our IEO:

- 1) Many ICT jobs are not well defined; often there are several titles for seemingly doing the same job duty. This issue will be addressed in ICT by providing clear description of each ICT job role and the possible job titles related to the role.
- 2) To make aware of the availability of the current ICT jobs with detailed description so that potential students can match their interest with the possible careers in ICT field. Unlike the traditional fields such as medicine or law, young people may not have a clear picture of what jobs are available to them should they choose to take up study in ICT. Many will want to match their interest and academic ability to what they believe to be the suitable jobs. Moreover, they will also be interested in knowing the progression of career should they choose a specific path.
- 3) To aid the investigation of ICT skills. By examining the skills require by each of these ICT jobs, a set of ICT skills can be compiled and made available in the ontology. We can then match these skills with those taught in the

various ICT curricula to see if any of these skills are not being covered. Often there are complaints that there is shortage of certain skills.

- 4) The ICT Job Ontology (IJO) defines ICT jobs. In today information society with ICT being used in just about every industry and ICT skills required in all levels of employment, it has become unclear to many what constitutes as “ICT job”. While many jobs involve the use of ICT as part of their duties, ICT jobs required deeper knowledge in ICT and equipped with certain ICT skills. It is therefore important to separate ICT jobs from those jobs that require the use of ICT as end-user.

Every ICT job requires specific skills and knowledge; so to be able to do the job, applicants must equip themselves with the right qualifications that provide those skills and knowledge. Having ICT jobs being clearly defined in IJO will help to establish link with ICT curriculum through its required skills and knowledge. This linkage enables potential students to see what course(s) they need to study if they have particular ICT jobs in mind.

The categorization of ICT jobs will be based on their functions rather than industry, for example, a Database Developer could be someone working for a software house or a bank or any other industry. Also, only ICT professional jobs will be included in the ontology so an Accountant who uses the computer extensively would not be included. Five main job seeking websites in Australia: SEEK.com.au, CareerOne.com.au, MyCareer.com.au, jobsearch.gov.au and jobs.com.au will be used to design the categorisation of ICT jobs.

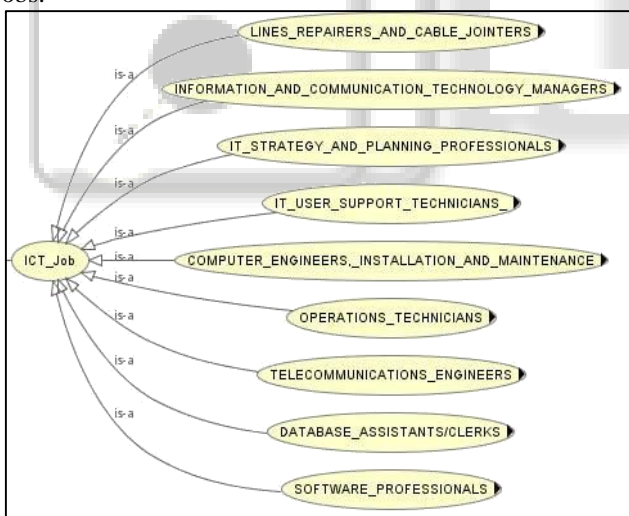


Fig. 4: Part of ICT Job Ontology

C. ICT skill Ontology

While ICT knowledge or concepts will be defined in ICT Curriculum Ontology, ICT skills will be defined in this ICT Skill Ontology (ISO). Figure 5 shows part of the ICT skill ontology.

ICT Skills is an important component in IEO because it acts as a link between ICT curriculum and ICT jobs.

By examining the skills that needed in each ICT job, a list of ICT skills can be compiled. Each skill will be defined with detailed description. The purpose of ICT skills is two-fold:

- 1) Employers can look up skills they need and find the courses (through ICT curriculum) that teach these skills. In the case that these skills are not found, they can flag that and the issues will be looked into. Currently, there is shortage in many skill areas but that information is not communicated to ICT course providers systematically.
- 2) Over time, certain skills may become obsolete which mean curriculum should be reviewed to reflect that. There is no point to teach skills that are no longer needed by the industry.

There are two main reasons why we are defining ICT skills separately: 1) Unlike ICT concepts, many of these skills are vendor specific 2) Some skills are closely related, for example, one skill may be the pre-requisite or co-requisite of another. Relationships like such need to be represented in the ontology. Many of these skills are also related to ICT concepts defined in the ICT Curriculum ontology.

Recognising that many ICT skills are vendor specific will aid in making decision when course providers choosing software or platform in their teaching.

“The Skills Framework for the Information Age (SFIA) provides a common reference model for the identification of the skills needed to develop effective Information Systems (IS) making use of Information Communications Technologies (ICT)” [14] . SFIA will be used as a guide to develop the ICT skill ontology.

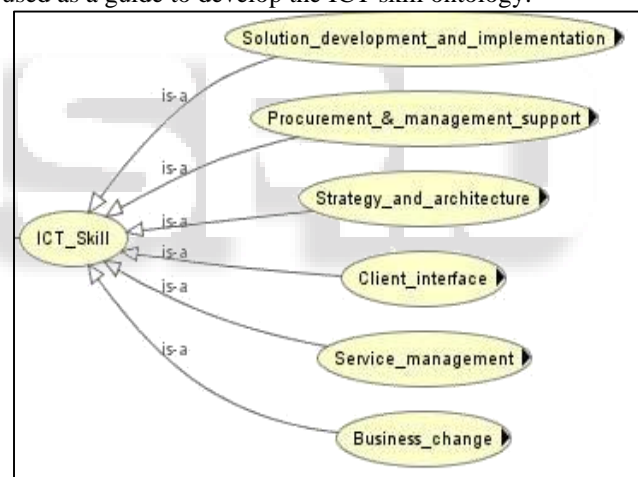


Fig. 5: Part of ICT Skill Ontology

D. ICT Research Ontology

Why is ICT Research being included in ICT Education Ontology?

ICT is a field that changes rapidly, new technologies and new ways of doing things emerge faster than we can keep pace with. Many of these are the outcomes of research being conducted in the field of ICT. There are thousands of ICT research project progressing daily and new ones add to the list every day, day after day. Many of these research projects are being conducted by academics and often they are joint venture with non-academic organizations. ICT research plays an important role in ICT education as research informs teaching and through collaboration in research, the relationship between academia and industry can thus be strengthened.

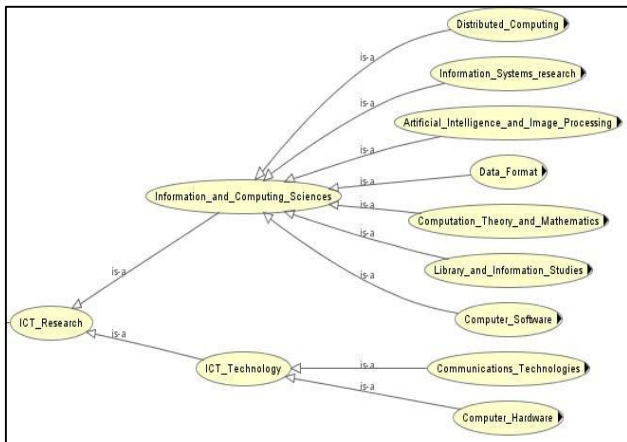


Fig. 6: Part of ICT Research Ontology

The purpose of IT research ontology is to classify the many different areas of research with in the ICT domain. However, it is not an easy task to define what constitutes ICT research given that this is a field that spreads across multiple disciplines. As an initial attempt, we shall classify ICT Research according to the standard lay out by the Australia Research Council's "The Excellence in Research for Australia (ERA) Initiative"[15]. Figure 6 shows part of ICT Research ontology.

VI. CONCLUSION

This paper has outlined an ontological solution to sustainable ICT education as a mean to address the sector's low student enrolment related issues. The proposed ICT Education Ontology (IEO) aims to provide clearly defined concepts in related areas such as ICT curriculum, ICT jobs, ICT skills and ICT research and to define the relationships amongst them. The purpose of IEO is to serve the key holders in ICT education: student, ICT education provider, ICT industry/employer where IEO serves as a mean of knowledge sharing. The development of IEO shall be an iterative process undergoing numerous rounds of rectification for improvement as well as undergoing stringent evaluation process in order for it to become useful.

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