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Examining the Efficacy of Personal Response Devices in Army Training

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Executive Summary

Benefits of personal response devices (PRDs) have been demonstrated in a variety of settings and disciplines in higher education. This study looked outside of higher education to investigate the efficacy of PRDs in an Army training course in terms of trainee performance, engagement, and satisfaction. Instructors were also surveyed to determine their perceptions of the impact of PRDs on student learning and engagement. Participant trainees reported that they were more engaged and had a better understanding of how well they understood the material because of the PRDs. Participants who had previously taken the course without PRDs reported a preference for the training with PRDs in terms of being more engaged, learning more, and enjoying the course more. No improvement in performance was detected when comparing final exam scores in these courses to prior courses that did not use PRDs. Instructors appeared to see benefits afforded to their students, but they also found the course more challenging to teach, highlighting the need for adequate training to use the new technology, and care taken to developing effective questions.

Keywords: personal response devices, clickers, army, military, enhanced training.

Introduction

Personal Response Devices (PRDs) have demonstrated success in terms of engagement (e.g., Caldwell, 2007; Hall, Collier, Thomas, & Hilgers, 2005) student satisfaction (e.g., Byrd, Coleman, & Werneth, 2004; Johnson, 2005; Lowery, 2005), and performance (e.g., Edens, 2009; Poulis, Massen, Robens & Gilbert, 1998; Ribbens, 2007) in a variety of venues. In the college classroom, PRDs have been shown to be beneficial in a variety of disciplines. The greatest extent of research has been in the science arena, but research studies have also been conducted in the fields of medicine, mathematics, business, social science, and more (Kay & LeSage, 2009). PRD use is also widespread at the K-12 level. Although research is much more comprehensive in higher education, a survey of K-12 teachers provided evidence that they use many of the same techniques used to make PRDs effective in higher education (Penuel, Boscardin, Masyn, & Crawford, 2007).

Research on the impact of PRDs has grown substantially in the 2000s, but this growth has not been evenly distributed across educational settings. A recent review of the literature by Kay and LeSage (2009) noted a lack of research outside of higher education and ics/science-based courses, and that conducting this research would help provide a fuller understanding of the impact of PRDs. The current study was performed to see if the effectiveness of PRDs will extend to a structured educational setting outside of higher education: an Army training course. PRDs are currently used in a variety of military trainings, such as in Army JROTC instruction (Worldwide Instructional Design System, 2010), Navy Submarine Training, and Air Force Medical Training (eInstruction, 2011). However, evidence of effectiveness in military settings is not readily available in the published literature.

Research Context

The Army training course under investigation (Combat Lifesaver training) is given to active and reserve Army personnel so that they can provide emergency medical care as non-medic soldiers in combat. Soldiers are instructed to treat and stabilize injuries including blast injury, amputation, severe bleeding, and penetrating chest injuries. Trainees use PRDs, a small handheld electronic device, to respond to questions embedded in presentation materials. The number or percentage of responses for each response option are displayed immediately and usually graphically. This provides immediate feedback which is beneficial to students (Edens, 2009), providing knowledge of how well they understand compared to their peers (Stuart, Brown, & Draper, 2004). Given that Combat Lifesaver training takes place during a condensed one-week period, a large amount of material is covered each day, making the use of daily/immediate feedback seem highly beneficial.

Other advantages of PRDs depend on the effectiveness of the questions, the climate in the classroom, and the instructor. PRDs have been shown to be more beneficial when questions promote discussion (DeBourgh, 2008) and deep thinking, as opposed to retrieval of facts (MacGeorge et al., 2008). Only a small amount of the material covered in Combat Lifesaver training can be learned easily and through basic memorization. For example, soldiers must be able to quickly determine what course of action to take in a combat situation when faced with a host of factors that weigh into their decision. Higher-level questions that focus on critical concepts, when asked with PRDs, should create time for trainees to reflect on the best course of action.

PRDs have also been shown to be more effective when instructors are aware of student performance and adjust the material they emphasize accordingly (Oerman & Gaberson, 2006). Trainee performance typically varies widely in a Combat Lifesaver training course. A typical course has trainees with varying rank, and because the course can be repeated numerous times some trainees have more direct exposure to the material than others. This diversity makes it appear very beneficial for instructors to quickly assess performance so that they can tailor each class.

Similar to the variations in classroom size across higher education’s colleges and universities, the Combat Lifesaver training size also varies based on the training site and available facilities. The always-changing military deployment schedule necessitates instructional techniques that are not dependent on classroom size. Most of the benefits of PRDs have been observed in large classrooms (Boyle, Nicol, Hamilton, & Dempster, 2001; Nicol & Boyle, 2003), where personal feedback and interaction with the instructor is more challenging. Smaller classrooms, however, have also been shown to benefit (e.g., Herreid, 2006). Although small classes make student discussion and engagement more feasible, PRDs can further motivate students to be involved (Lea, 2008). Students benefit from defending their answers to their peers, clarifying points of uncertainty or misunderstanding, and increasing their critical thinking abilities (Frederickson & Ames, 2009).

At a surface level, it appears that the effects of PRDs that have been documented in higher education should extend to Combat Casualty training. At the most general level, PRDs enhance student engagement, which promotes active learning (Hall et al., 2005). A more active learning environment leads to more engaged students and is believed to enhance student learning (Chickering & Gamson, 1987). Greater engagement has been shown when all students respond to questions posed by the instructor, rather than just a few who typically respond (Frederickson & Ames, 2009). In contrast to many advanced Army laboratory training environments, the lecture environment for Combat Casualty training has typically been passive. It was suspected that training would greatly benefit from an environment that promoted active engagement. The following study looks at the impact of PRDs in an Army training course by investigating their impact on student performance, engagement, and satisfaction. Benefits and challenges to instructors were also investigated.

Method

Participants

A sample of 117 soldiers taking a Combat Lifesaver course at a National Guard Training Center participated in the study. Sixty-five of the soldiers were taking the Combat Lifesaver course for the first time. Fifty-two of the soldiers were repeating the course. Thirty-four of the repeaters were taking the course for the second time, and the remaining 18 had taken the course between three to five times before.

The sample was obtained from three Combat Lifesaver training classes. Two were offered in May of 2010, each of which had 50 trainees. The third class was offered in August of 2010 and had seventeen trainees.

The instructors of these three training classes also participated in the study. All classes were team taught with two instructors. Instructors varied by class, with the exception of one instructor who took part in two classes. This resulted in five different instructors. All were experienced in teaching the Combat Lifesaver training course.

Materials and Procedure

Instructors involved in the study had previously taught the course without PRDs using a PowerPoint presentation that was broken into ten lessons. As part of the study, instructors used a revised ten lesson PowerPoint presentation with an average of approximately eight questions per lesson. The questions were developed with curriculum experts from the Army National Guard Medical Operations Instructional Team for response using PRDs. The PowerPoint presentation was also reduced in length to focus on content most valuable to the instructors and curriculum experts and to allow for time to devote to the PRD questions. Instructors delivered the presentation using the CPS Pulse student response system sold by the company eInstruction. This system enabled questions to be incorporated directly into the PowerPoint presentation, and instructors provided aggregate class results in chart form immediately following student responses. All soldiers were provided with the CPS Pulse response devices during the lectures.

Participants completed the Combat Lifesaver course over a five-day period. Each lecture was followed by a lab and simulation exercise, the content of which was not altered during the study. Following the complete delivery of the lecture part of the course, a questionnaire was given to each of the soldiers. This questionnaire, which is provided in Appendix A, asked soldiers about their satisfaction, engagement, and perceived amount of learning in the training. The questions made specific reference to their use of the PRD, which instructors referred to as “clickers.” Participants who had taken the course in the past were also asked questions related to their preference for this new “clicker” version of the training vs. the “non-clicker” version.

A questionnaire was also given to instructors at the end of each course. This questionnaire, provided in Appendix B, asked instructors about their preferences regarding their teaching of the new “clicker” version vs. the “non-clicker” version, as well as how they perceived students to benefit from the new version.

Performance was also evaluated by comparing results of the standard exam that accompanies all Combat Lifesaver courses. This exam is taken at the completion of the course and must be completed with a successful pass rate of 70 percent in order for trainees to receive Combat Lifesaver certification. The exam consisted of 40 multiple-choice questions that are directly related to the content covered in lecture. The exam was not altered in any way from previous trainings for this study. Exam questions differed from the questions that were included in the PowerPoint presentation to be answered using the PRDs, but they did assess the same content.

Results

Trainee Satisfaction and Engagement Ratings

Survey responses from soldiers were analyzed using a chi-square test of goodness of fit to determine whether solders showed agreement to positive aspects of the training course and to the incorporation of PRDs. The results for each survey item are presented in Table 1. All questions resulted in the soldiers showing significant agreement to the positive aspects of the course and use of PRDs. When asked specifically about the use of the PRDs, participants showed significant agreement (89.3% strongly or somewhat agreed) that the PRDs made the class more engaging, χ^2 (1, N = 112) = 69.14, p < .001, ω = .79. Participants also agreed (87.6% strongly or somewhat agreed) that the PRDs made them better aware of how well they understood the material, χ^2 (1, N = 113) = 63.94, p < .001, ω = .75.

Table 1: Analysis of Soldier's Perceptions of Enhanced Lecture

Survey Question	% Satisfied	N	χ^2	ω	*p*-value
Training exceeded my expectations	86.8	114	61.895	0.737	<.001
Confident I could apply learned skills in combat	93.8	112	85.75	0.875	<.001
Found training course engaging	95.6	113	93.885	0.912	<.001
Clickers made class more engaging	89.3	112	69.143	0.786	<.001
Clickers made me better aware of how well I understood materials	87.6	113	63.938	0.752	<.001
I could easily follow along with the textbook	80.5	113	42.133	0.611	<.001

An independent-samples t-test revealed no significant differences across participants who were repeating the course vs. first-timers in terms of PRDs making the class more engaging, t(110) = 1.00, p = .339, or in terms of PRDs making them better aware of how well they understood the material, t(111) = .838, p = .414.

Questions asking participants who were repeating the course to rate their preference for the version of the course with vs. without PRDs were also evaluated using a chi-square test of goodness of fit to determine whether solders showed a preference for the PRD version. The results for each survey item are presented in Table 2. This table shows that all questions resulted in a significant preference for the version of the course that includes PRDs. Over eighty percent (82.4%) indicated that they would rather repeat the clicker version of the course, and the same percentage indicated that they were more engaged in this version of the course. An even higher percentage (84.3%) indicated that they enjoyed the PRD version more than prior versions. Participants also gave a significant preference for having learned more in the PRD version (72.5%), but this preference resulted in a smaller effect size (χ^2 (1, N = 51) = 10.37, p < .001, ω = .45) than did questions related to engagement and enjoyment.

Table 2: Analysis of Soldier's Perceptions of Enhanced Lecture vs. Traditional (Past)

Clicker to non-clicker training Questions	% Indicating Preference (above neutral)	N	χ^2	ω	*p*-value
Repeat clicker version	82.4	51	21.353	0.647	<.001
More engaged in clicker version	82.4	51	21.353	0.647	<.001
Learned more in clicker version	72.5	51	10.373	0.451	<.001
Enjoyed clicker version	84.3	51	24.02	0.686	<.001
Had easier time following along with book in this version	62.6	51	3.314	0.255	0.069

Qualitative Feedback from Trainees

Participants were asked to explain in what ways, if any, the response clickers helped them learn the material. The majority of responses fell into three major categories of perceived benefits from (1) various types of interactivity, (2) reinforcement of material, and (3) ability to participate with anonymity. Almost half of all soldiers (48.7%) remarked on various ways that the PRDs made the course more interactive. The answer given most frequently was that answering the questions kept them more engaged/motivated. Almost a quarter of respondents (22.22%) remarked on positive ways the PRDs reinforced the material. This included benefits from thinking about and forming a response to the question that is followed by immediate feedback, as well as how the discussion with the instructor following the answer reinforced their understanding. Finally, a handful of participants (6.84%) remarked on the benefits of the anonymous environment that the PRDs promoted, allowing them to participate when they might not otherwise, without the influence or worry of getting the answer incorrect in front of peers.

Participants were also asked to write about how they would improve the use of clickers in the training class. Nearly sixty percent of participants (59.85%) remarked on program glitches such as computer freezes and clickers not responding, making up 70% of all the comments provided. A handful of unique responses, such as utilizing timers for self-read portions and incorporating short videos to maximize interactivity further demonstrated the participants' engagement with the training.

Performance

The final exam performance of participants in the study was compared to the performance of all trainees having taken a course without the use of PRDs during the previous year at the same National Guard Training Center. Scores from 1,065 trainees were included in this cohort. An independent-samples t-test revealed no significant difference between the exam scores of participants in the PRD classes ($M = 87.28$, $SD = 6.59$) with all trainees who took the non-PRD course the prior year ($M = 88.43$, $SD = 7.22$), $t(1180) = 1.54$, $p = .124$, $d = 0.16$.

Instructor Perceptions

Instructors, all having taught the course prior to incorporating PRDs, provided ratings to questions comparing the course with vs. without the use of PRDs. Only five instructors participated in the study, which meant that too few responses were collected to conduct any inferential statistics on their preference for the use of PRDs. However, no instructors indicated a clear preference for the training that used PRDs. Many of the instructors had a slight preference (between clicker and no preference) for the course with PRDs in terms of teaching that version again, being more engaged, and believing that the soldiers learned more. None of the instructors, however, favored the PRD training (even between PRD and no preference) in terms of it being easier to teach.

Instructors were also asked a series of open-ended questions about the enhanced course. The main benefits they saw from the clickers was that they made the trainees more attentive/alert and that the trainee feedback was an asset so that they could identify topics needing further discussion. Three of the five instructors also commented that a main benefit to trainees was the discussion that was elicited following a question. When asked what changes they would make if they were to continue using this format, the main suggestions were related to the questions in terms of revisions to some of the questions, moving questions to the end of the lecture, and trimming the number of questions to reduce the impact on lecture time.

Discussion

Trainees and instructors both indicated that the PRDs enhanced engagement in the classroom. Participant trainees also perceived themselves as learning more, but this was not supported by increased exam performance. The participants' performance scores, however, were very high prior to the use of PRDs. It is likely that a ceiling effect may have made it difficult to detect increased performance due to the PRDs. Testing, in addition to the final exam, wasn't feasible in this training, but future performance measures developed for the sole purpose of measuring PRD effectiveness are needed to better understand PRDs' impact on performance.

Participants who had taken the same training in the past but without PRDs indicated that they preferred the course with PRDs. The choice wasn't as clear for the instructors. Instructors appeared to see the engagement and learning benefits afforded to their students, but they also reported that PRDs made the course more difficult to teach. Three issues appeared to be central to this difficulty: technical problems, classroom management, and required changes in pedagogy.

Instructors needed to become familiar with new software to implement the PRDs. That software was sometimes incompatible with other technology used, resulting in program freezes. Clearly, instructors will find the course difficult to teach while experiencing technical problems, highlighting the importance of substantial training to make them comfortable using the new technology. Participants also needed adequate training to operate the new technology. Instructors were given training to use PRDs, but none of the instructors were experts, and most experienced technical difficulties during the trainings. The extent of technical difficulties was probably more prevalent in these trainings than in higher education settings because of the high level of computer security necessary at a National Guard Training Center. Many of the participants noted the technical difficulties when asked how to improve the training. But even with these glitches, trainees still showed a clear preference for the inclusion of PRDs.

A second concern of the instructors was how they could discuss the questions effectively without increasing lecture time. The discussion elicited by the questions, which is crucial to the effectiveness of the PRDs, created timing and class management issues for some instructors. The discussions appeared to take increased instructional time, and the transition back to the lecture was a challenge for some instructors. Such issues would likely be eliminated or greatly reduced with additional training and experience using the PRDs. With experience, instructors should recognize that clickers eliminate the need to discuss topics that are well understood and allow more time to discuss topics where misunderstandings are evidenced (Anderson, Healy, Kole, & Bourne 2011). Smooth transitions back to the lecture will occur as instructors establish standard classroom protocols for PRD use.

A third instructor concern related to question wording. Some of the textbook derived questions were too simple to evoke meaningful discussion. The research team collaborated with the instructors to improve this aspect of the training, but more work in this area appears to be needed.

Finally, the effective use of PRDs requires that instructors capitalize on the learning that takes place when students actively interact with content. The discussions that take place following PRD use are crucial to enhancing understanding. Instructors who have not used this approach will need extensive training regarding the pedagogy behind effective PRD use.

Conclusion

Overall, the use of PRDs made the training class a more engaging and enjoyable setting for trainees. However, instructors must invest time to comfortably operate the software and to adjust to a different way of teaching. This makes it important that instructors are sufficiently motivated to use the PRDs, and this can be done through proper pedagogical training, and by providing sufficient experience operating the software. Under these circumstances, it appears that PRDs can be a valuable addition to Army training.

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Appendix A: Questions for Trainees

Section 1

Please complete this section if this is NOT the first time you have taken this training course. Skip to Section 2 if this was your first time.

1) How many times have you taken this training (including this course)? _____

2) Circle the number that best reflects whether, if given the choice, you would prefer to repeat the instructional portion of this course in the *clicker* or *non-clicker format*.

The *clicker version* refers to the format of the training that you just completed that included the use of a personal response clicker. The *non-clicker version* refers to training that you had in the past that did not use the personal response clickers.

1	2	3	4	5
I would rather repeat the clicker version of training		I have no preference		I would rather repeat the non-clicker version training
1	2	3	4	5
I was more engaged in the clicker version of training		I have no preference		I was more engaged in the non-clicker version
1	2	3	4	5
I learned more in the clicker version of training		I have no preference		I learned more in the non-clicker version
1	2	3	4	5
I enjoyed the clicker version of training		I have no preference		I enjoyed the non-clicker version of training

Please write your answers to the following questions in the space provided.

4) Which lesson, if any, was most improved in the clicker version? Please explain.

Section 2

Use the following scale to indicate how much you agree with each of the statements that follow. This is for everyone to complete.

1	2	3	4	5
Strongly agree	Somewhat agree	Neutral	Somewhat disagree	Strongly disagree

This training exceeded my expectations. 1 2 3 4 5

I am confident that I could successfully use the skills I've learned in combat.
1 2 3 4 5

I found this training course engaging. 1 2 3 4 5

The use of personal response clickers made the class more engaging.

1 2 3 4 5

The use of personal response clickers made me better aware of how well I understood class material.

1 2 3 4 5

Please write your answers to the following questions in the space provided.

1) In what ways, if any, did the response clickers help you learn the material?

2) How would you improve the use of response clickers in this training class?

Appendix B: Questions for Instructors

1) Circle the number that best reflects whether, if given the choice, you would prefer to repeat the instructional portion of this course in the *clicker* or *non-clicker format*.

The *clicker version* refers to the format of the training that you just completed that included the use of a personal response clickers. The *non-clicker version* refers to training that you had in the past that did not use the personal response clickers.

1	2	3	4	5
I would rather teach the clicker version of training		I have no preference		I would rather teach the non-clicker version training

1	2	3	4	5
I was more engaged teaching the clicker version of training		I have no preference		I was more engaged teaching the non-clicker version

1	2	3	4	5
I think the soldiers learned more in the clicker version of training		I have no preference		I think the soldiers learned more in the non-clicker version of training

1	2	3	4	5
I enjoyed teaching the clicker version of training		I have no preference		I enjoyed teaching the non-clicker version of training

1	2	3	4	5
The course was easier to Teach		I have no preference		The course was easier to teach

Please write your answers to the following questions in the space provided.

1) In what ways did your instruction benefit from the use of personal response clickers, if any?

2) In what ways do you think the trainees benefited from the use of response clickers, if any?

3) If you continue using this format of instruction, what changes would you make, if any?

Biographies

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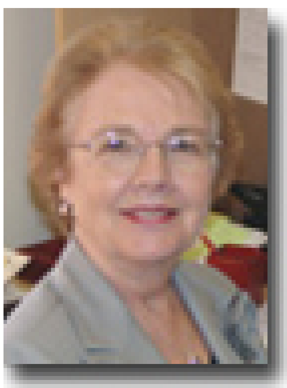

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A Template-Based Short Course Concept on Android Application Development

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Executive Summary

Smartphones are a common accessory to provide rich user experience due to superior memory, advanced software-hardware support, fast processing, and multimedia capabilities. Responding to this trend, advanced engineering systems tend to integrate mobile devices with their solutions to facilitate usability. With many young students showing interest in learning mobile application development, conventional electrical engineering undergraduate education cannot meet the needs of this workforce due to fast changes in mobile technology and limited curricula hours. Template-based learning (TBL) methods may overcome these limitations by shortening the learning cycle through fast hands-on introduction to development tools, basic programming, and application development and integration process. Students manipulate code fragments in provided templates, and compile, embed, and run applications. They also implement new applications reusing fragments from other similar templates. TBL modules can be integrated in pre-existing conventional courses to provide basic and fast exposure to the subject. This paper provides an example of a TBL template library for Android phones, which has been used in a classroom setting to collect student attitude data and assess efficiency of the TBL approach.

Keywords: Learning, Mobile Applications, Mobile Education

Introduction

Mobile phones are technologically advanced devices that provide more and more communication and other services. Numerous applications exploit superior memories and cameras, various wireless channels for voice and data, inertial and satellite positioning systems, advanced signal and graphics processors and accelerators, etc. Acquisition, processing, and visualization of various media also are common due to advanced software platforms and applications.

Educators are inspired to use cell phones to communicate learning content in new formats as Millennials (ages 18-34) are by far the most technologically advanced user group, with a 95% cell phone ownership (Caverly, Ward, & Cavarly, 2009; Zickuhr, 2012). Mobile learning, or m-learning, is defined as the acquisition of any knowledge or skill through using mobile technology (Geddes, 2004). This concept extends to

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ubiquitous learning (Sakamura & Koshizuka, 2005), the concept of learning "anything at anytime and anywhere," as people spend more than 50% of their time outside their office or classroom (Hayes, Joyce, & Pathak, 2004) and essential learning subject exists in our daily environment (Laine, Sedano, Joy, & Sutinen, 2010). Mobile learning also is related to e-learning, which enhances education through access to learning materials over the Internet (Rosberg, 2001). All of these concepts belong to a broader framework of technology enhanced learning (TEL) (Lytras, Gasevic, & Ordonez De Pablos, 2008), which exploits technological innovations to improve the efficiency and cost effectiveness of traditional teaching methods.

In Japan, a survey of 333 Japanese university students concerning m-learning (Thomton & Houser, 2004) revealed that 100% of them own a mobile phone, 99% send email on their phones, exchanging some 200 email messages each week. 66% email peers about classes; 44% email for studying. In contrast, only 43% email on PCs, exchanging an average of only two messages per week. Most of the subjects preferred receiving educational materials on mobile phones rather than PCs and liked using phones for teaching. Recent examples of m-learning efforts can be found in Tribal's Digital Learning Studio (www.mlearning.org) for example.

M-learning likely will enhance education by closing digital gaps as the largest growth in mobile phone ownership is predicted to come from people from low socio-economic status (Portio Research, 2012). It also essentially will affect education in developing countries, where mobile phones have a much higher penetration rate than laptop and desktop computers (Ullrich, Shen, Tong, & Tan, 2010).

Even though there are psychological, pedagogical, and technical limitations for m-learning (Shudong & Higgins, 2006) (small screens, typing inconvenience, etc.), it can be claimed that, in general, students are willing to use their mobile devices for educational purposes.

Most m-learning applications are designed for content delivery and learning facilitation. For example, mobile apps such as myHomework (https://myhomeworkapp.com/) allow students to track their course material on their smartphones. In addition to being a platform for content delivery and user experience enrichment, the mobile phone can also serve as a "technology kit," which can be used to learn computing aspects and application development itself.

With almost four billion wireless connections in 2008 worldwide, the cell phone industry generated vast services and large job markets. Undergraduate education should address this demand by properly training the workforce for the future. Unlike computer and information sciences (Tam & Chen, 2006), electrical engineering (EE) students have very limited exposure to mobile programming but must work in multidisciplinary fields where mobile devices are incorporated in control chains of various systems.

The diversity of mobile platforms, dramatic changes in industry, and limited curricula hours make it challenging to integrate mobile computing courses in conventional undergraduate EE programs. Figure 1 schematically illustrates significant market share redistributions of mobile phone platforms in evolution using data from the Gartner Smartphone Marketshare Reports (www.gartner.com). Android OS platform (http://developer.android.com/index.html) recently gained popularity as an open source platform that relies on Java language for mobile application development. Even though platform penetration dramatically changes over time and other platforms may prevail in the future, Android is attractive for education needs as it provides free development resources, which will help to scale up successful efforts for broader dissemination and student adoption. Additionally, many student-owners of Android phones can work within a platform that they are familiar with and use on an everyday basis.

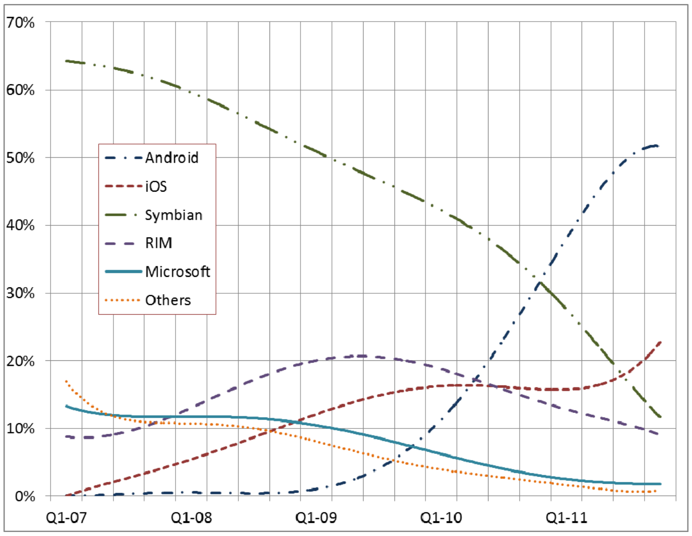


Figure 1: A schematic illustration of worldwide mobile smart-phone OS platform market share evolution, from 2007 to 2011 using data from (www.gartner.com).

This paper investigates template-based learning (TBL) for Android mobile application development to help overcome EE program constraints as described above. The idea is to develop learning modules that can be integrated in electrical engineering courses (e.g., signal processing or communications courses). Due to short cycles, students learn by exploring already available templates, which can be manipulated to a limited extent to gain initial application development experience. While the idea of using template designs in programming was exploited previously (Al-Imamy, Alizadeh, & Nour, 2006; Schank, Linn, & Clancy, 1993), this paper extends a similar approach to mobile programming. As cognitive aspects of learning in mobile programming are not addressed fully yet, we rely on our own learning experiences to hypothesize concerning efficient learning strategies. Particularly, two learning alternatives can be considered: (1) initial fast-track exposure to the subject to see the big picture, and (2) conventional routine acquisition of knowledge and experience.

The focus of the paper is on the first stage of mobile programming, which introduces students to the subject. The sample codes are available in a predesigned library of application templates that can be used or manipulated. In this approach, students can quickly develop functional apps without having to go into depth with mobile programming or spend a great deal of time coding from the ground up. The library can be distributed or placed on a server for remote development as well. Topics about signal and image processing and wireless communications can be studied in relation with the hands-on labs on mobile devices. Camera images and video, audio and voice signals, wireless connectivity standards, signals from accelerometers, and many more built-in phone features can be used in designing such labs.

Thus, the research question is the following. How efficient can template-based short learning modules be as fast introductions to challenging areas of mobile programming typically covered by a dedicated course or sequence of courses? Here, “efficiency” is understood as a transformative factor: (a) change of conventional attitudes; (b) gaining confidence; and (c) ability to successfully complete assignments in the focus area and to develop their first apps independently.

The rest of the article has been organized further in the following way. A brief description of the proposed template-based education philosophy is presented. Development tools are described in the following section. Then, examples of template mobile applications are reviewed and one of them is presented in detail. The next section describes the image processing toolbox to demonstrate how templates can be collected in libraries. A quiz application developed by the authors is briefly described as a relevant supportive self-assessment tool. The next section describes a case study using TBL in a classroom setting and provides evaluation results by analyzing survey results concerning student attitudes and assignment grades. Finally, the research effort is summarized in the conclusion.

Philosophy of the Approach

This section addresses the rationale of a template-based approach and its relation to the state-of-the-art. It is necessitated by the fact that formulating structured solutions, understanding program execution, and learning a rigid syntax and commands can be challenging for beginners of all ages. Multiple programming languages have been created and environments have been built to make programming more accessible to beginners, particularly young programmers. Several programming languages and development environments were designed for the purposes of making some of the abstract concepts more concrete, alleviating some of the cognitive load associated with problem solving and computation, and motivating students to learn programming. For instance, BlueJ, the interactive Java environment, (www.bluej.org) is an integrated Java environment specifically designed for introductory teaching about object-oriented programming through code visualization. Another example is Scratch (http://scratch.mit.edu/) from MIT Media Lab, which was designed to help young children to program through a drag-and-drop interface. After being exposed to an easier learning experience, students start programming using general-purpose languages and professional development tools.

Educational programming environments have many advantages for beginners compared to professional text-based and visual programming tools. Many of the abstract concepts have been hidden from the user as well as the advanced tools that are typically associated with industry-grade development environments. At the same time, transition to professional tools might be challenging. In some of these programming systems, students might focus on the fun part of the system more and forget about the main goal, which is programming. Similarly, design tools such as MIT App Inventor (http://appinventor.mit.edu/) facilitate application development, but do not expose students to the "real development" world. Rather, it provides an easy-to-understand interface to app development.

TBL's goal is different. It is to provide real experiences with professional tools in a short time. Exposure to the big picture has its own educational value; it will alleviate technology fears and may motivate further in-depth studies. Using a metaphor, kids can use toys to pretend to help their parent fishing, but helping the parent with small tasks during "real fishing" with real tools is a completely different experience.

Unlike conventional application development learning approaches (Lutes, 2012) the TBL process will provide students with ready-to-run programs, giving them the ability to modify those and immediately experience the programming process and see the results. The goal is to educate using a compiling and integration process, familiarize them with software development kits/IDE, and provide them "real" exposure to the professional world. For more advanced students, the templates will help to shorten the coding cycle by reusing samples from templates. A well-designed template could be used to support the learning process as well as the software development process.

Templates have been used to facilitate conceptual understanding of programming concepts (Al-Imamy et al., 2006; Schank et al., 1993; Yuen & Liu, 2011). Yuen and Liu (2011) studied how a video game template supported and guided conceptual understanding of object-oriented programming (OOP) as students used it to create their own interactive multimedia games. In using templates, Yuen and Liu found three levels of interaction that result in better conceptual understanding. First, visual feedback from the games, specifically unexpected behaviors, brought attention to flaws in the software design. When students encounter these errors, they begin another level of interaction with the template, which is to explore the template resources. This exploration can lead to the discovery of important information, discovery of relationships between resources, and model code that can later be used. As they explore, students begin to refine their code as well as their understanding of the code. At the cognitive level, the template scaffolds conceptual understanding as it provides the foundation or incomplete code base from which students can build their programs. If designed correctly, the template code can be used as models or exemplars that guide students' thinking and coding.

In the case of the course described in this paper and in Yuen and Liu (2011), templates are used as cognitive tools. Cognitive tools are computer-based tools that assist learners in the reorganization of cognitive structures to support higher order cognitive activities (Jonassen, 2006). The purpose is to engage learners in problem-solving tasks that are within their zone of proximal development; that is, the cognitive tools help learners go beyond what they can do on their own by providing necessary scaffolding (Vygotsky, 1978). Scaffolds generally include cues and prompts, models, and guidance, which are tailored to individual students. Eventually, assistance is slowly retracted, known as fading, which results in the learner being able to accomplish those tasks alone.

As the learning modules are offered in lab formats, including step-by-step procedures, experience with tools will be educative and not be stressful. The beginners will learn progressively, from basic to more advanced modules. Templates use graphics and animation for more appealing experience.

Learning using templates abstracts many of the development steps by pre-populating design and code modules. They automate the packaging and deployment processes to make the entire software development lifecycle less intimidating and more obvious for students. These simplifications allow students and their instructors to focus their attention on the broader picture before concentrating on coding details. The differences between template-based programming and regular programming are illustrated in Figure 2. There are seven steps in the creation of an Android application. These steps include designing, coding, compiling, pre-verification, packaging, testing, and deployment. The steps are illustrated in Figure 2 in blue. The color red shows a shortened cycle of TBL, where designing and coding stages are simplified to code manipulation, and the testing stage is a primitive visual validation of results. The other four stages (in Eclipse IDE box) are the same in both approaches.

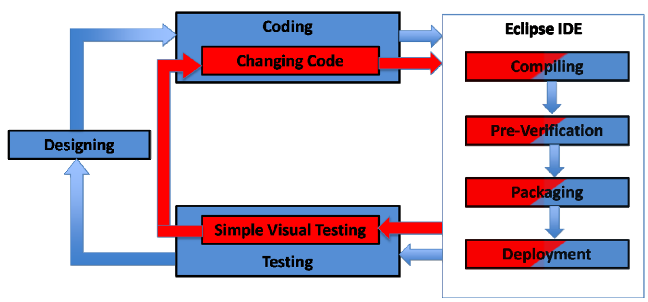


Figure 2: Template-based system vs. conventional programming process.

Development Tools

The templates are implemented in the Java programming language ("JAVA tutorial," 2012) using the Android Software Development Kit (SDK) (http://developer.android.com/index.html) in the Eclipse Integrated Development Environment (IDE) (www.eclipse.org). Eclipse is a convenient development environment, which provides an extensible plug-in system. Executable 'apk' files are deployed onto Android compatible mobile devices. Students who are familiar with Java programming can easily work with Android SDK. The Android Developer Tool (ADT) is an Eclipse plug-in, which provides different versions of emulators replicating Android phones. Sample image processing templates are available in a JJIL open source image processing library, developed in Java (http://code.google.com/p/jjil).

Template Apps Used

The following section describes the template applications used for the projects. It includes a conventional “Hello World” application, which is used to learn the development environment and perform basic modifications. Then, progressively, other template apps are described along with related learning aspects. The application “Simple Animation” is chosen for detailed explanation while others are just summarized.

Learning Modules

“Hello World” Application (Figure 3a): The “Hello World” program is typically the first program that students learn when introduced to a programming language. This application is designed to introduce the first timer to fundamentals of syntax and building a user interface, which in this case displays “Hello World” on the screen. The objectives for this unit were to have students be able to do the following:

- launch the Eclipse IDE and Android SDK on a computer,
- become familiar with the Java language,
- understand how different objects in Java interact,
- change the message text in the template code,
- test applications in Android SDK emulator, and
- install and run applications on the mobile devices.

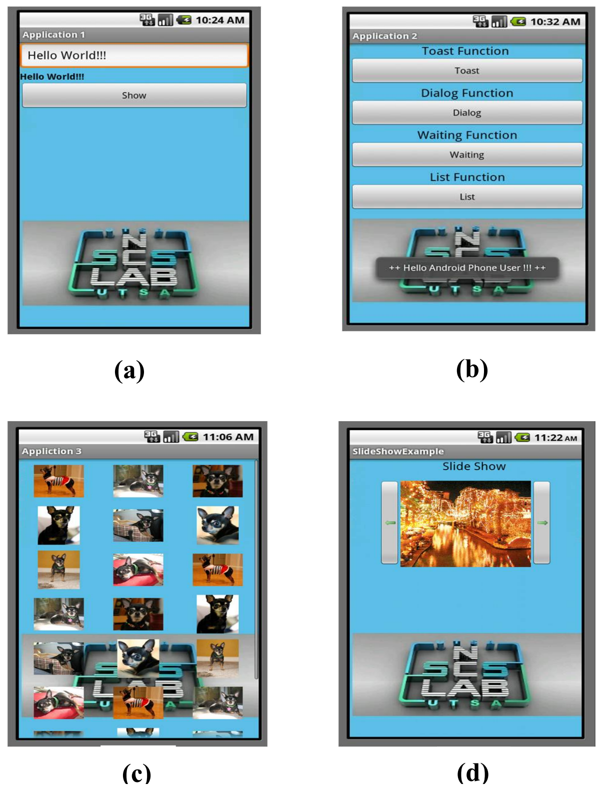


Figure 3: (a) ‘Hello World’ Application, (b) ‘OnClick Example ‘ Application, (c) ‘Image Gallery’ Application, (d) ‘Slideshow’ Application

“OnClick Example” Application (Figure 3b): The “OnClick Example” application demonstrates the addition of buttons and handling events that activate upon clicking. It uses texts and other visual effects to manifest the changes that happen on the screen in response to user interaction. From studying this example, students are expected to learn:

- the significance of methods used in Java,
- how to create new objects in Java,
- how methods work,
- handling events in Java, and
- to customize and assign events or tasks to buttons.

“Image Gallery” Application (Figure 3c): This example helps build an image gallery application with the scrolling effect applied when scrolling up and down from one set of images to another. This application introduces the following topics:

- the digital representation of an image,
- creating an array and managing its content,

- resizing digital pictures, and
- giving functionality to the up-down scroll panel.

"Slideshow" Application (Figure 3d): In this example, students use the template to build an image slideshow application by using images from both project resources and the Internet. The application contains buttons that handle all user actions to move from one image to another or back. This application introduces the following:

- working with URL resources,
- giving functionality to the right-left scroll buttons, and
- manipulating in-project/out-project images.

"Simple Animation" Application

Objectives: This application introduces a basic animation application and building a user interface, which in this case displays a black screen with the touch pad functionality. Students are expected to learn the following from this unit:

- digital color concepts,
- visualizing geometric shapes and their representation in program logic,
- understanding and manipulating the position of elements on the screen using co-ordinates along "x" and "y" axes, and
- animating static geometric shapes to create patterns.

Code Walk Through: There are two critical methods in the *SimpleAnimation.java* class. In the *DrawView* method the figure shape and color is set by *paint.setStyle* and *paint.setColor* methods. In the *OnDraw* method, the background color is set to white using the *canvas.drewColor* method. The second method also defines the drawing figure shape and size. The shape can be changed from a circle to a rectangle or other shape. Some code fragments from the *"Simple Animation"* application are shown in Sample Code 1.

Sample Code 1: Code Fragments from 'Simple Animation' Application

```
public DrawView(Context context) {
      super(context);
      setFocusable(true);
      setFocusableInTouchMode(true);
      this.setOnTouchListener(this);
      paint.setStyle(Style.FILL);
            // Change the 'Style.FILL' to 'Style.STROKE' to change
            the figure style.
      paint.setColor(Color.rgb(255, 0, 0));
            // Change the '255, 0, 0' to any integer numbers within
            the range 0-255 to change the figure color.
      paint.setAntiAlias(true);
   }
   @Override
   public void onDraw(Canvas canvas) {
            canvas.drawColor(Color.WHITE);
             // Change the background color "Color.WHITE" to
            "Color.GRAY" or any other color from the given list.
            int size=6;
            // Change the '6' to any integer number to change the
            figure size.
            for (Point point : points) {
            // Change the figure shape by uncommenting one of the
            lines above. Note: Once you uncomment any line with
            "canvas" comment the active line.

            // canvas.drawPoint(point.x, point.y, paint);

            canvas.drawCircle(point.x, point.y, size, paint);

            //canvas.drawRect(point.x, point.y, point.x+size,
            point.y+size, paint);
      }
   }
```

Code Manipulations: The code presented as a template in the Eclipse IDE contains highlighted sections of code that can be changed in succession to observe and grasp the overall structure of the mathematical logic and the program syntax that work to create shapes, colors, and effects that change position and direction based on user interaction (See Table 1).

Testing: Before deploying the application, it must be tested using a base common emulator device that mimics the functionality of an actual device on a user's computer. This emulator is part of the Android SDK and provides functionalities that are sure to be present in the majority of devices running the OS and/or platform for which the application is targeted.

Table 1: Code Manipulations Applied to 'Simple Animation' Application

Manipulations	Code
Change the animation figure style from 'FILL' to any other style	paint.setStyle(Style.FILL);
Change the figure color.(Change'255','0', and '0' in prentices with the new integer numbers within the range '0-255')	paint.setColor(Color.rgb(255, 0, 0));
Change the screen background color from 'WHITE' to any other color.	canvas.drawColor(Color.WHITE);
Change the figure size from '6' to any other size.	int size=0;

Change the animation figure shape to the new one such as rectangle, line, circle, or triangle shape. (Comment and uncomment the lines)	//canvas.drawPoint(point.x, point.y, paint);
	canvas.drawCircle(point.x, point.y, size, paint);

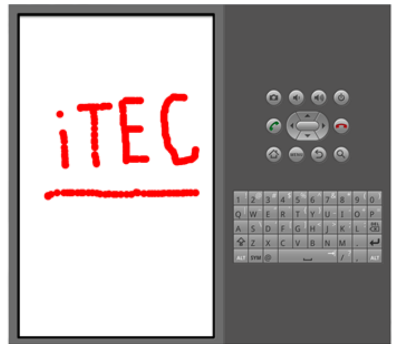
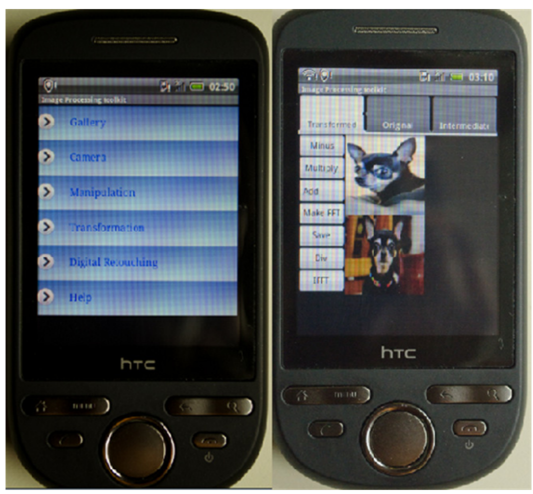


Figure 4: 'Simple Animation' Application shown in emulator.

After completing the desired customization as shown in Table 1 in the application template, it is ready to run on the emulator. We have the option to change the emulator device by selecting a new device from the project properties option. This enables us to observe the application's compliance with basic as well as advanced handsets. Figure 4 shows us the result of running the "Simple Animation" on a standard Android SDK capable emulator.

Deployment: There are two ways to deploy the executables on a mobile device. The first is via an ad-hoc connection between user computer and handset. This can be done via either a USB cable or a Bluetooth wireless connection, based on user device capabilities. Most Android devices allow a user to install applications via these connections. The second way is via the Internet by publishing the developed application in Web stores. This project, we accessed via the USB cable deployment option.



Menu

Gallery
- Select image from gallery

Camera
- Launch camera
- Select image from SD card

Manipulations
- Crop image
- Skew image
- Transpose
- Rotate
- Scaling
- Add images
- Subtract images
- Clone image to image2

Transformations
- FFT
- FFT domain processing
- DCT

Digital Retouching
- Adjust brightness
- Invert image
- Histogram
- Salt and pepper noise

Gaussian noise
- Average filter
- Median filter
- Min-Max filter
- Laplace filter
- Sobel filter
- Gaussian smoothing
- Hough transform

Figure 5: (Left) Menu structure of used library on Android phone; (Right). Sample demonstration of FFT domain processing with two images

Image Processing Template Apps

The learning flow starts with a simplified "design" (template manipulations) followed by "coding," "pre-verification," "deployment" and "testing." The toolkit abstracts many of these steps to make it easier for students to handle the process.

This section demonstrates how template apps can be clustered in libraries to address specific application areas. The EE students deal with signal and image processing algorithms through related templates and hands-on exercises to study the effects of the algorithms on images captured by a handset camera or downloaded from the Internet. The image processing algorithms are collected in a template library and partitioned as 1) manipulations; 2) transformations; and 3) digital retouching (see Figure 5). A detailed description of this module has been reported by the authors in Golagani, Esfahanian, Akopian, and Saygin (2012) and is reviewed here. The "manipulations" category includes simple mathematical operations such as add/subtract two images, scale, crop, clone, transpose, skew, and rotate an image.

The "transformations" contains algorithms that convert images in the spatial domain to the frequency domain and inversely from the frequency to the spatial domain (discrete cosine transform and fast Fourier transform). "Digital retouching" consists of a set of image evaluation operations such as histograms, noise removal, and edge detection filters. Some sample real time images are stored in the gallery; otherwise, the user can take pictures using the built-in camera. The images on the handset screen are placed under different tab controllers, namely "transformed," "original," and "intermediate," to compare processed and original images.

Sample applications are "median," "averaging/mean," and filters. The filters are a sliding window functions (i.e., each pixel of the image is replaced by a value), which is computed using a window of neighborhood samples.

Sample code 2a and 2b depict operation of the median and mean filters in the window. The median filter effectively removes impulsive salt-and-pepper noises while mean filters are useful for filtering Gaussian noises. Figure 6 illustrates denoising examples by these filters on handset screens. By default, a 3x3 kernel is defined, which can be changed by students. In case a filter performs a linear operation, (i.e., samples in the window multiply to kernel weights), then various kernel selections may result in low-pass, high-pass, and edge detection filters. Examples of template manipulations for implementing edge detection filters using the "averaging" display are shown in Table 2. Figure 7 illustrates edge detection using the Laplace filter, and Figure 8 demonstrates two-dimensional convolution in the frequency domain.

Sample Code 2: (a) Median Filter Averaging (Mean) Filter, (b) Mean Filter

(a)

```
int  center =4; //center  index, index starts from'0'
int[] window  = new  int[2*center+1];
//vector to hold pixels from 3x3 neighborhood window
for(int y=1;y<=height-2;y++){
 for (int x=1 ;x<=width-2;x++){
 // fill the window with pixel values
     int k=0;
    for (int j= -1;j< =1; j++){
      for (int i= -1;i< =1; i++){
        window[k]= inputimg.getPixel(x+i , y+j);
        k++;
      }
}
  Arrays.sort(window); // sort in ranking order   modifiedpixels[x][y]=window[center];
 //replace pixel with median
  }
 }
```

(b)

```
int  kernelsize = 3 ;  int  total_kernelelements= 9;
int  window[][] = new int[kernelsize][kernelsize];
int[][] kernel={{1,1,1},{1,1,1},{1,1,1}};
for (int  y=1;y < height-2;y++) { //slide in 'y'dimension
   for (int  x=1;x < width-2;x++){ //slide in 'x'dimension
  //get input pixel values to kernel
int  r=0,g=0,b=0;
for (int  i=0;i<kernelsize;i++){
   for (int  j=0;j<kernelsize;j++){
//get R,G,B values from input image and add all elements
      r= (r+ kernel [i][j]*RgbVal.getR(window[i][j]));
      g= (g+ kernel [i][j]*RgbVal.getG(window[i][j]));
      b= (b+ kernel [i][j]*RgbVal.getB(window[i][j]));
  } }
// compute average
 r= r/total_kernelelements;  b=b/total_kernelelements;
 g=g/total_kernelelements;
 int  mean  = RgbVal.toRgb((byte) r,(byte) g, (byte) b);
```

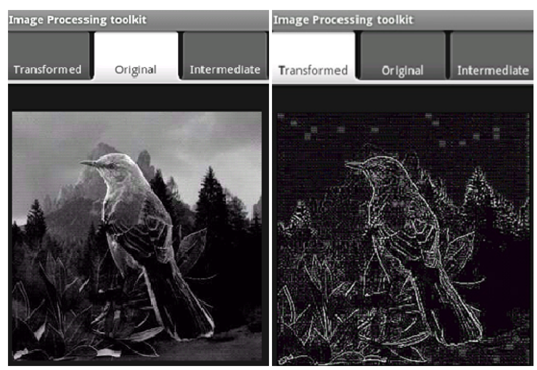
(a) (b) (c)

(d) (e) (f)

Figure 6: (a) Original 'Barbara' image; (b) 'Barbara' image corrupted by salt & pepper noise; (c) Corrupted "Barbara" image restored by a median filter; (d) Original 'Lena' image; (e) 'Lena' image corrupted by Gaussian noise; (f) Corrupted "Lena" image restored by average or mean filter

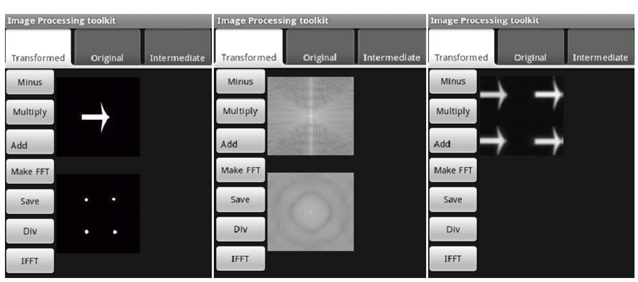
Table 2: Code Manipulations Applied to Edge Detection Filters

Manipulations	Code
Apply Sobel1 kernel. This makes edge detection in vertical direction and smoothing in horizontal direction	**int[][]** kernel = {{1,0,-1},{2,0,-2},{1,0,-1}};
Apply Sobel2 kernel. This makes edge detection in horizontal direction and smoothing in vertical direction.	**int[][]** kernel = {{1,2,1},{0,0,0},{-1, -2,-1}};
Apply 3x3 first Laplace kernel.	**int[][]** kernel = {{1,1,1},{1,-8,1},{1, 1,1}};
Apply 3x3 second Laplace kernel	**int[][]** kernel = {{0,-1,0},{-1,4,-1},{0,-1,0}};



(a) (b)

Figure 7: (a) Original image; (b) Laplace filtered image for edge



(a) (b) (c)

Figure 8: (a) Original two images; (b) FFT applied; (c) convolution applied and its IFFT

Quiz Application

One can also develop apps that support learning assessment. An example is implemented to support student self-assessment. Once students complete their projects with templates, they can assess their knowledge by launching the quiz application. This page launches with five random questions queried from the SQLite (http://www.vogella.com/articles/AndroidSQLite/article.html) database. Since Android provides full support for the SQLite database, the database created will be accessible by name to any class within the application. SQLite is readily available on every Android device. Once SQL statements for creating and updating the database are defined, then the database is automatically managed by the Android platform. Each question appears on a single page (Figure 9). Click "next" to go to the next question. Finally, the "submit" button appears, which gives a pop up message showing the score of the attempted quiz. At this stage, the quiz application is used for self-assessment only.

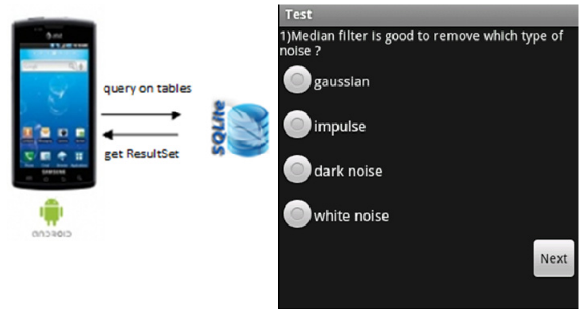


Figure 9: Sample screen of Quiz in this toolkit

Learning Module Assessment

A short course workshop module (Table 3) has been integrated in the wireless communications course, which is offered by the Electrical and Computer Engineering Department at the University of Texas at San Antonio (UTSA) during Spring 2012. About thirty-five students participated in the workshop for a total of 8 days for 1 hour 15 minutes per day. The effort is part of a broader educational initiative of the Interactive Technology Experience Center (iTEC) at the UTSA on implementing technology enhanced learning for undergraduates and outreach (http://itec.utsa.edu/).

The efficiency of the template-based learning is assessed through the follow-

Table 3: Short Course Program

Introduction to the Android Application Development (Class duration: 1h15min)	
Class 1	**Introduction.** History. Operation Systems (OS). Mobile phone development market
Class 2	**Integrated Development Environments (IDE).** NetBeans IDE and Eclipse IDE for Java based application development The students learned: ▪ Find and install the IDEs ▪ Create first project in Eclipse IDE
Class 3	**Introduction to Java.** Basics of Java programming language and examples
Class 4	**Android Platform.** Introduction to Eclipse IDE/Android SDK development environment and to the basics of android application development. The students learned: ▪ Find and install the Android SDK. ▪ Integrate Android SDK with Eclipse IDE. ▪ Create first android emulator. ▪ Create first android project. ▪ "Hello World!!!" - first Android application. ▪ Run and test the application on the emulator.
Class 5	**Template-Based Applications.** Learn by manipulating templates. The students learned: ▪ Application 1. ('Hello World' application) ▪ Application 2 ('OnClick Example' application) ▪ Application 3 ('Image Gallery' application) ▪ Application 4 ('Slideshow' application) ▪ Application 5 ('Simple Animation' application) ▪ How manipulate application templates ▪ How install and test applications on handsets
Class 6	**Android GUI Development.** Basics of the android GUI development. The students learned: ▪ The basics of Android GUI development. Integrate different GUI components (such as buttons and checkboxes) to the application. *("Temperature Converter" application was used as an example)* ▪ Install the device drivers and connect the mobile device to the Eclipse IDE/Android SDK
Class 7	**Advanced Android Application Development.** Examples of Image processing applications: median and averaging filters, edge detection, convolution in frequency domain.
Class 8	**Project Presentation:** In this class, Instructor formulated project assignments and requirements. Directions and hints are provided to students. The workshop was concluded with the Question/Answer session.

ing criteria: (a) change of conventional attitudes; (b) gaining confidence; and (c) ability to successfully complete assignments in the focus area and develop their first apps independently. The preliminary results of this assessment were originally discussed in Golagani et al. (2012), but more detail and discussion regarding the entire learning module are presented here.

To assess course effects on student attitudes, both pre- and post-workshop surveys are conducted.

Pre-workshop survey questions and data are presented in Table 4. Similar to other studies (Lang et al., 2007), the responses are scaled using answer options: the scale goes from 5-excellent to 1-poor for the first question, the scale goes from 5-high to 1-low for the second question, the scale goes from 5-hard to 1-easy for the third question, and the scale goes from 5-yes to 1-no for the last question.

Most of the students reported low or average programming experience with only 5% highly assessing their skills (mean = 2.39). Initial perception of students on the difficulty of mobile programming is average with mean = 2.71. Most of the students think that careers in mobile programming are rewarding (mean = 3.9), about 60% positive.

Table 4: Students' Pre- Workshop Feedbacks

Questions	Mean	SD	Percentage of 5 and 4 selections
How do you grade your programming skills? {Excellent 5 – 1 Bad}	2.39	0.9	5%
How do you grade your interest in Mobile Application Development? {High 5 – 1 Low}	4.13	1.1	83%
At this point, how do you perceive the difficulty of mobile phone programming? {Hard 5 – 1 Easy}	2.71	1.05	22%
Do you think that the mobile programming is a rewarding career but you have doubts on possible difficulties when pursuing it? {Yes 5 – 1 No}	3.9	1.06	60%
How do you grade your interest in having more Android Application Development experience? {High 5 – 1 Low}	4.27	0.98	85%
Were homework 1 applications useful as initial learning experience? {Yes 5 – 1 No}	4.21	0.72	83%
Did homework 2 ("Temperature Convertor" Application) help to advance your Android exposure? {Yes 5 – 1 No}	4.48	0.72	94%
Modifying known applications as in the last project (image processing) might help to overcome programming skill limitations for beginners. {Agree 5 – 1 Don't agree}	3.79	1.16	62%
Were Android Application Development tutorials helpful? {Yes 5 – 1 No}	4.49	0.81	92%
Were PowerPoint presentations helpful? {Yes 5 – 1 No}	4.31	0.91	89%

Table 5 shows post-workshop survey results. The majority of students, approximately 76% (Mean = 3.93), changed their opinion on the difficulty of mobile programming and think that they can develop Android applications if needed (69%, mean = 3.89). Ninety percent of students (mean = 4.41) understood the application development process. Eighty-two percent (mean = 4.03) would consider the usage of mobile phones in their senior design projects. End of semester monitoring confirmed that 12 students eventually did so. Overall, students were satisfied, as their expectations were met (87%, mean = 4.34). This demonstrates the efficiency of the approach in terms of "change of attitudes" and "gaining confidence."

There were three homework assignments on application development: (1) replicate the design of a set of template applications; (2) design a "currency conversion" application using template "temperature conversion" application; and (3) investigate the "image processing apps" toolkit and implement filters with various kernels. All homework assignments were assessed positively by students (83%, 94%, and 62% for assignments 1, 2, and 3, respectively), which inferred that students had good experiences with the template-based assignments.

Table 5: Students' Post- Workshop Feedbacks

Questions	Mean	SD	Percentage of 5 and 4 selections
Has this workshop changed your perception on the difficulty of mobile phone programming? {Yes 5 – 1 No}	3.93	1.31	76%
Do you think that you would be able to develop Android applications if needed? {Yes 5 – 1 No}	3.89	1.21	69%
Has this workshop clarified the phone application development and integration process? {Yes 5 – 1 No}	4.41	0.89	90%
Might this workshop influence your opinion on a possible use of Android Application in your senior design project? {Likely 5 – 1 Unlikely}	4.03	1.13	82%
Are your expectations from the workshop met? {Yes 5 – 1 No}	4.34	0.79	87%
How do you grade your interest in having more Android Application Development experience? {High 5 – 1 Low}	4.27	0.98	85%
Were homework 1 applications useful as initial learning experience? {Yes 5 – 1 No}	4.21	0.72	83%
Did homework 2 ("Temperature Convertor" Application) help to advance your Android exposure? {Yes 5 – 1 No}	4.48	0.72	94%
Modifying known applications as in the last project (image processing) might help to overcome programming skill limitations for beginners. {Agree 5 – 1 Don't agree}	3.79	1.16	62%
Were Android Application Development tutorials helpful? {Yes 5 – 1 No}	4.49	0.81	92%
Were PowerPoint presentations helpful? {Yes 5 – 1 No}	4.31	0.91	89%

A general assessment survey is summarized in Table 6. Students found the mobile application development workshop to be excellent (92%, mean = 4.34), interesting (95%, mean = 4.48), relatively easy (67%, mean = 3.72), useful (93%, mean = 4.41), valuable (91%, mean = 4.31), motivational (63%, mean = 3.34), and balanced in effort (54%, mean = 3.27). Presentations and tutorials were helpful for 89% and 92 % of students, respectively. Eighty-five percent (mean = 4.27) of students were motivated to learn more about mobile application development.

Table 6: Students' Feedbacks about the Workshop

How do you grade Mobile Application Development workshop in general?					Mean	SD	Percentage of 5 and 4 selections
Excellent	5	-	1	Bad	4.34	0.92	92%
Interesting	5	-	1	Boring	4.48	0.89	95%
Easy	5	-	1	Hard	3.72	0.91	67%
Useful	5	-	1	Useless	4.41	0.85	93%
Valuable	5	-	1	Worthless	4.31	0.91	91%
Motivational	5	-	1	Dry	3.34	1.15	63%
Effortless	5	-	1	Labor-intensive	3.27	0.82	54%

Lutes (2012) reported many challenges when teaching mobile programming even for dedicated semester-long course settings. For the short course described in this paper the students learned essential concepts of mobile programming as evidenced by the results. Ninety-four percent of students had grades B and higher for assignment 1. Eighty-three percent of students had grades B and higher for designing their first independently developed "currency converter" application in assignment 2. This addresses the third efficiency criterion "ability to develop apps independently." Similarly, 83% of students had grades C and higher for completing the very challenging "image processing app" homework assignment 3. All three homework grades demonstrated efficiency in terms of the three criteria defined above. In other words, template-based education appears to be a very efficient learning approach for mobile application programming.

Conclusion

The paper summarized the study on effectiveness of template-based undergraduate learning for mobile application development in electrical engineering departments, which may not provide conventional course tracks for comprehensive learning on the subject due to curricula hours' constraints. Short modules are integrated in a conventional course and basic exposure to mobile computing was provided without specific prerequisites. Survey results demonstrate high efficiency of the approach. It motivates students to elaborate similar topics further and consider Senior Design topics based on mobile apps. Moreover, templates served as hands-on exercise for students to work on topics covered in their conventional signal and image processing courses by capturing and manipulating images from phone cameras.

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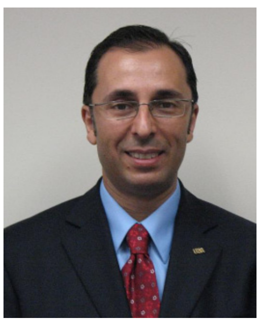

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The Effects of ICT Environment on Teachers' Attitudes and Technology Integration in Japan and the U.S.

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Executive Summary

The present study analyzes the effects of Information and Communication Technology (ICT) environment on teachers' attitude toward technology integration in Japanese and U.S. elementary schools. Teacher's attitude plays an important role in influencing the effectiveness of ICT education from a variety of perspectives. A number of studies have been done regarding teachers' attitude toward ICT, but there is very little research concerning international comparisons. The interest of observation in the present paper is the cross-cultural comparison between Japanese elementary school and U.S. elementary school teachers. The purpose of the paper is to identify the factors that affect teachers' perception of ICT and how they differ between the two countries.

Past research supports the usefulness of technology for students to engage in collaborative learning. Also, when teachers view technology as a possible asset, the effectiveness of ICT is at maximal. Research in the field of ICT has provided evidences of a positive impact on students' learning, but elementary school teachers may have mixed opinions about the use of technology. From the latest statistical analysis and literature reviews, it appears that Japan may be more hesitant to ICT education on societal and individual levels.

The technology acceptance model (TAM) was utilized to identify the teachers' perceived ease of use and usability (PEUU), perceived usefulness (PE), and attitudes toward using technology (AT). The demographic and environmental sections (gender, age, teaching experience, the technology availability, and the frequency of ICT use) were added in the survey to examine additional factors that may affect the

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teachers' attitude toward ICT. The data was collected from the teachers at the elementary schools in Hokkaido (northern Japan) and in southern Utah in the U.S.

Independent t-tests analysis showed that the U.S. teachers had more positive PEUU, PU, and AT than did the Japanese teachers. Chi-square analysis on the ICT environmental factors revealed that the U.S. teachers were provided with richer technology environments. Overall, the U.S. teachers' use of interactive boards, number of computers, and use of computers outnumbered the Japanese counterparts to a great extent. Multiple regression analysis between the demographics and the TAM indicated that the younger U.S. teachers' age significantly predicted the positive PEUU, and the Japanese gender was a significant predictor of PEUU, PU, and AT (male participants answered more positively). Multiple regression analysis between ICT environments and the TAM showed that the number of interactive boards in class was a strong predictor of Japanese teachers' PU and AT, and the number of computers in a lab significantly predicted the Japanese teachers' AT. In addition, the U.S. teachers' PEUU significantly predicted the computer use.

One limitation arose in the present study regarding the sampling equivalence between the U.S. and Japan. In the U.S. the majority of teachers were female but that was not the case in Japan. Diversity of the U.S. education is a challenging factor in comparing with Japanese education in which curriculum tends to be homogeneous throughout the country. Nevertheless, the present study found significant relationships in the teachers' attitudes, the quality of ICT environments, and other factors that affect their perceptions of ICT between Japan and the U.S. As the popularity of ICT education increases worldwide today, the U.S. teachers' positive beliefs about ICT and better quality of technology equipment may put the U.S. students in an advantaged position compared to the Japanese students.

Keywords: ICT, Teacher's attitude, and Technology integration.

Introduction

The utilization of technology in the elementary classroom is becoming increasingly vital in a global society. There are many benefits to using technology as an educational tool. Technology helps students visualize abstract ideas and makes it easy to find reliable information (Qing, 2007). Students' motivation and confidence are increased when technology is integrated into classroom instruction (Mouza, 2005; Torff & Tirotta, 2010). Computer engagement also improves student's academic achievement (House, 2012; Mercier & Higgins, 2013). A number of Web 2.0 technologies and open sources are currently available. Teachers at any grade level can easily create collaborative activities for students on the web (Holcomb & Beal, 2010; "IRA members embrace," 2011). For example, the use of blogs for peer feedback improves elementary student's writing quality (Chen, Liu, Shih, Wu, & Yuan, 2011) and a course management system helps facilitate cooperative learning in secondary classrooms (Soh, 2011). Interactive whiteboards are also common classroom technology especially in elementary schools. A study showed that students from fourth to eighth grades have a favorable attitude toward the use of interactive whiteboards and believe that interactive whiteboards have positive effects on learning (Şad & Özhan, 2012). While most schools still use a stationary interactive whiteboard, which requires teachers to stay at the front of the classroom, a newer model with mobile technology allows teachers to move around classrooms and monitor students during instruction (Robertson & Green, 2012). Other mobile devices, such as iPads and tablets also have much potential and can be incorporated into classroom lessons to improve student's academic performance (Cohen, 2012; Haydon, Hawkins, Denune, Kimener, McCoy, & Basham, 2012; Sullivan, 2013). Researchers found that iPads help special needs students improve basic skills, such as reading and writing, and increase their attention and interests in learning (Fernández-López, Rodríguez-Fórtiz, Rodríguez-Almendros, & Martínez-Segura, 2013).

According to the report by the National Center for Education Statistics in 2009, 97% of elementary and secondary teachers in the U.S. had at least one computer available in the classroom every day and 93% of those computers had Internet access. Although the vast majority of teachers had access to computers in the classroom, only 40% of teachers said that they used those computers often during instructional time (Gray, Thomas, & Lewis, 2010). On the other hand, in Japan, the rate of regular classrooms equipped with computers is 35% (MEXT, 2011). Also, only about 30% of teachers in Japan are provided computers by the school (Shimizu, Yamamoto, Horita, Koizumi, & Yoshii, 2007). The Internet accessibility rate in Japanese schools is 99.99%. Nevertheless, the rate of teachers who use computers and the Internet in classes is about 50%, as is the rate of teachers who have confidence in using computers in classes (Shimizu et al., 2007).

The attitude of the teacher toward using technologies in the classrooms is a major factor in how successful technology integration will be (Tabata & Johnsrud, 2008). Voogt (2010) found that teachers who use technology extensively in their lessons tend to have a high level of confidence in pedagogical technology skills and focus on a learner-centered approach. They are more engaged in professional development activities and collaboration with colleagues than teachers who don't use technology very often. A number of factors must be accounted for during analysis of teachers' negative attitudes toward technology integration. In the US, some influential factors identified by past research include computer anxiety, perceived importance of computers, computer enjoyment, and the time commitment to learn new technology and teach it to the students (Christensen, 2002). The experience of technology use affects teachers' anxiety and attitude, and in particular, the higher the frequency of such experiences is, the more it affects anxiety and attitude (Takayama, 1993). Teachers' fears of being replaced by technology also create negative attitudes (Qing, 2007). While most teachers believe technology integration in the classroom will enhance their instruction, many consider the training they receive in order to utilize new technology insufficient, and available technology in schools is limited (Kazu, 2011). The technology training is often offered at inconvenient times or at other locations on different computers than those used in the classroom (Hixon & Buckenmyer, 2009). Although training experiences in themselves do not directly affect anxiety and attitude toward technology, they have indirect effects on anxiety and attitude through the mediation of other factors such as daily use of computers as a result of having training (Takayama, 1993). Schrum and Levin (2013) examined successful professional development models for technology integration from eight exemplary schools. Through observations and interviews, they identified four critical factors for successful technology training. Those factors include formal district level activities, opportunities for summer workshops, informal professional development (e.g., peer assistance) and individual teacher development (e.g., taking graduate level courses and building professional learning communities). Furthermore, research shows that teachers' pedagogical beliefs (e.g., philosophies of teaching and learning) are correlated to their technology integration (Kim, Kim, Lee, Spector, & DeMeester, 2013). In order to change teachers' beliefs, schools must develop strong leaderships. Also, school principals should not only be an official supervisor, but be a personal advisor to provide assistance to individual teachers and staffs (Kim et al., 2013).

Businesses around the world have embraced technology, yet many schools preparing the workforce of the future are not making the same strides. Baule (2007) suggests that in order for teachers to use technology effectively, "the technology must be easy to use; it must be engaging and flexible; and it must provide results" (Action Research section, para. 3). Teachers have the inherent ability to shape future generations. When teachers have positive attitudes toward computers, students' perceptions of computers are also positive (Christensen, 2002). Although most teachers in the U.S. have ready access to technology in the classroom, many do not use it effectively during instruction (Gray et al., 2010). Even teachers with a high level of technological competence and confidence still relied on a traditional teacher-centered approach (Prestridge, 2012). Further investigation is warranted to decipher factors that affect teachers' attitudes towards technology.

The purpose of the study is to examine teachers' attitudes and technology integration in U.S. and Japanese elementary schools. Nearly 75% of people both in Japan and the U.S. have access to a computer at home and use the Internet (Suzuki, 2012; U.S. Census 2010). However, when it comes to technology integration in the classroom, Japanese schools tend to take more conservative approaches than US schools (Salcito, 2010). Traditionally, Japanese classrooms are teacher-centered and students are expected to be quiet, whereas US classrooms emphasize collaboration and open discussion (Takeya, 1992). Morrone (2012) attributes Japan's stagnation in integrating technology to the Japanese university entrance exam that dictates the curriculum in Japanese secondary education. The Japanese university entrance exam tends to be based on the conventional content and methods; therefore, it keeps everything new and innovative like learning with technology off the lesson contents in high schools.

In Japan, students are tracked at the end of 9th grade according to academic ability and required to take high school entrance exams. Research shows that Japanese students at the top ranked high schools tend to use computers in the classroom less frequently than those in other schools. Also, elementary students in the large cities tend to use computers more often than those living in the rural areas, while this trend is reversed in middle grade and high school levels (Benesse Educational Research and Development Center, 2008). In the US, the frequency of technology use in the classroom does not differ between elementary and secondary schools both in the city and the rural district (Gray et al., 2010).

In addition, a study by Joshi and his colleagues (Joshi, Pan, Murakami, & Narayanan, 2010) has shown that Japanese kindergarten teachers were more skeptical and unsure of the benefit of computers. They believed that hands-on, sensory experience should be more emphasized in developing young children's performance compared to the U.S. teachers. Jung, Kudo, and Choi (2012) also claimed that excessive online collaborative activities tend to have negative effects on Japanese learners and cultural differences must be considered in designing instructions. Further, Elwood and MacLean (2012) compared student's willingness to use technology in Japan, Malaysia, and Cambodia. Their study revealed that students' technology attitudes are different, depending on the country.

In summary, various factors affect teacher's technology integration. Past research suggests that cultural factors may also influence teachers' use of technology in the classroom, as well as their technology attitudes. Thus, the present study seeks to answer the following questions, "What are factors that affect elementary teachers' attitudes toward using technology in the classroom and how do attitudes compare and differ between Japan and the U.S., which are two technologically advanced nations but are different in teaching traditions? Does the amount of technology used differ, and if so, how often and what type?" The study will help us find what changes need to occur to improve teacher attitudes and perceptions towards technology to allow for further integration in the classroom.

Methods

In the present study, the researchers utilized the teachers' technology attitudes survey developed by Holden and Rada (2011). Their survey is based on earlier research on the technology acceptance model (TAM). Davis (1989) first introduced the TAM. He claimed that perceived ease of use and perceived usefulness predict an individual's intention to use technology as well as actual usage behavior. His theory has been recognized and studied by many researchers. Holden and Rada expanded the TAM and revised the original scale by adding usability elements to the perceived ease of use. Their study showed that the revised scale with perceived ease of use and usability influenced the TAM components more than the original scale with perceived ease of use only.

In this study, several additional items also have been included in order to examine the classroom environments and teachers' technology usage in their schools. The survey consists of five sections: demographics (gender, age, teaching experience), technology availability (the number of interactive boards, computers in class and lab), frequency of ICT use (computer, internet, interactive board), perceived ease of use and usability (PEUU), perceived usefulness (PU), and attitudes toward using technology (AT). The PEUU, and PU were assessed using a seven-point Likert scale (1 = strongly disagree, 2 = moderately disagree, 3 = somewhat disagree, 4 = neutral, 5 = somewhat agree, 6 =moderately agree, 7 = strongly agree). The AT was assessed using a seven-point semantic differential scale (i.e., good—extremely, quite, slightly, neutral, slightly, quite, extremely—bad) (Holden & Rada, 2011).

A group of researchers in the U.S. and Japan collected data separately. The survey was translated into Japanese for Japanese participants. Participants in the U.S. were recruited from elementary teachers at seven different schools in Utah. All participating schools in the U.S. were located in rural areas and the student populations in each school were between 500 and 600. A majority of teachers in those schools were White. Approval from the superintendent of the school district was obtained via email, and the mentor faculty contacted each elementary school principal to explain the study. After obtaining permission from school principals, the U.S. researchers visited each school and distributed the survey. Japanese participants were recruited from elementary teachers in Hokkaido, Japan. The Japanese researchers collected their data from teachers of different schools in Hokkaido by (1) visiting two schools in Asahikawa city, a public elementary school and an attached school to a university of education, (2) attending school teachers' meetings with participants from different schools in the city, and (3) distributing the questionnaire set up in the SNS specifically constructed for elementary teachers in Hokkaido. Student populations in most participating schools ranged from 200 to 500.

According to the World Databank database, the U.S. and Japan are the top two countries for technology expenditures (Orfano, 2010). In the U.S., the state government allocates technology budgets to each school based on the number of students. Therefore, technology expenditures in schools can be different, depending on the state. Utah has been recognized as one of the top states in the use of digital technologies in the governments for the past several years (Center for Digital Government, 2012). Therefore, technology accessibility in Utah is higher than that of other states. In Japan, the Ministry of Education, which is equivalent to the U.S. Department of Education, is in charge of technology expenditures for all schools in Japan and allocates the budgets, which is based on the number of students (MEXT, 2011). Thus, technology accessibility in schools is more likely to be the same or similar throughout Japan.

All teacher participants completed the survey voluntarily and remained anonymous. Data were collected from April to June 2012. Chi-squared, t-test, and regression analysis were conducted to examine the data.

Results

The Participants' Characteristics

Table 1 shows a summary of participants' characteristics in the U.S. and Japan. In the U.S., 99 elementary teachers participated in the study (Male=11, Female=88). The participants' ages were distributed among 22-30 (19.2%), 31-39 (24.2%), 40-48 (23.2%), 49-57 (24.2%), and ≥58 (9.1%). More than half of the U.S. participants reported having 6-10 years or 16 plus years of teaching experience (29.3% respectively). In Japan, 67 elementary teachers participated in the study (Male=32, Female=35). The participants' ages were distributed among 22-30 (35.8%), 31-

39 (28.4%), 40-48 (26.9%), and 49-57 (9.0%). Also, teaching experiences were distributed among 1-5 years (31.3%), 6-10 (20.9%), 11-15 (13.4%), and over 16 (34.3%).

Table 1: Participants' Demographics

	Items	Percent (N) U.S.	Percent (N) JP
Gender	Female	88.9% (88)	52.2% (35)
	Male	11.1% (11)	47.8% (32)
Age	22-30	19.2% (19)	35.8% (24)
	31-39	24.2% (24)	28.4% (19)
	40-48	23.2% (23)	26.9% (18)
	49-57	24.2% (24)	9.0% (6)
	≥58	9.1% (9)	0% (0)
Teaching Experience	1-5 years	20.2 % (20)	31.3% (21)
	6-10 years	29.3% (29)	20.9% (14)
	11-15 years	21.2 % (21)	13.4% (9)
	≥ 16 years	29.3% (29)	34.3% (23)

Independent T-Tests on PEUU, PU, and AT

Factor scores were used to calculate the average scores of PEUU, PU, and AT, and independent t-tests were used to compare the U.S. and Japan. The results showed significant differences between the two countries in all three categories. The U.S. participants were more positive for PEUU, $t(164)=-6.164$, $p<.001$, PU, $t(164)=-8.046$, $p<.001$, and AT, $t(89.31)=-6.571$, $p<.001$ than Japanese participants.

Differences in ICT Environment and Technology Usage

The results of chi-square tests demonstrated that the ICT environment and technology usage differ between the two countries (see Table 2). The significant differences were found in the following categories: the number of interactive boards in class, the number of computers in class, frequency of computer use, frequency of Internet use, frequency of interactive board use. ($\chi^2=89.61$, df=2, $p<.01$, $\chi^2=88.60$, df=6, $p<.01$, $\chi^2=61.55$, df=3, $p<.01$, $\chi^2=43.19$, df=5, $p<.01$, $\chi^2=77.14$, df=5, $p<.01$, respectively). The U.S. schools were better equipped in terms of ICT and the teachers had more access to ICT than the Japanese counterparts. About 85% of the U.S. participants said they have interactive boards in their classrooms, whereas less than 15% of the Japanese participants said they do. Over 90% of the U.S. participants have at least one computer in their classrooms, while 65% of the Japanese participants said there was no computer in the classroom (see Figures 1-5).

Table 2. Chi-Square Tests: ICT Environment and Technology Usage

	χ^2	*df*	*N*
Interactive Board in Class	89.61**	2	177
Number of Computer in Class	88.60**	6	178
Number of Computer in Lab	7.14	3	177
Use of Computer	61.55**	5	176
Use of Internet	43.19**	5	174
Use of Interactive Board	77.14**	5	172

*p <.05 **p<.01

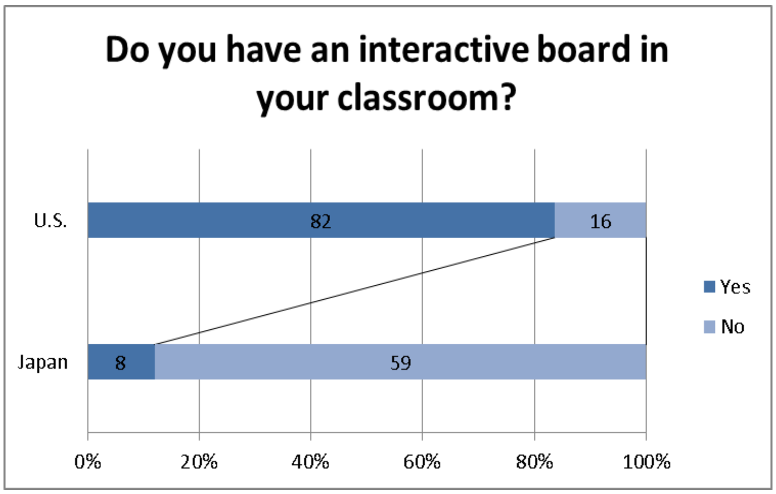

Figure 1: The number of interactive boards in class

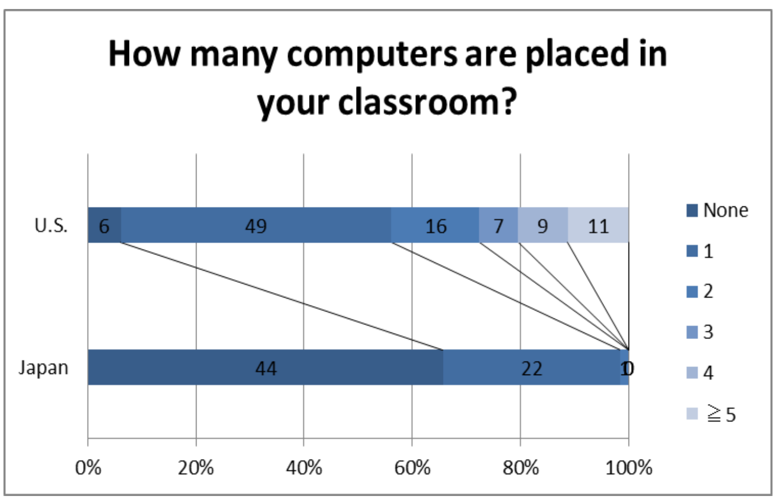

Figure 2. The number of computers in class

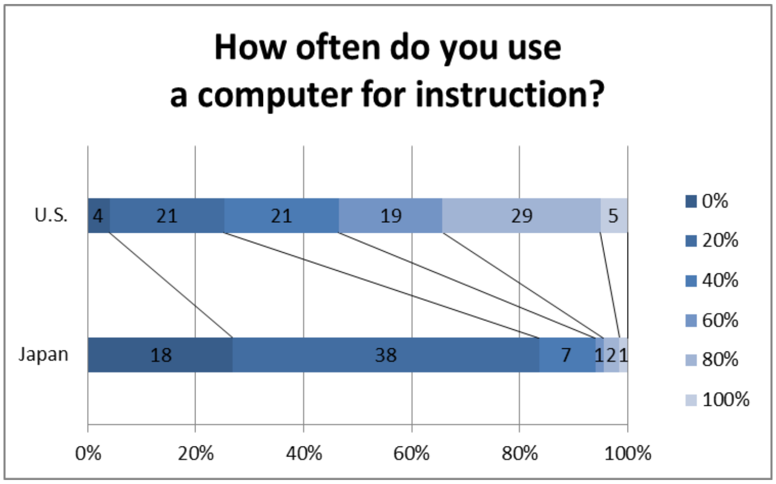

Figure 3. Frequency of computer use

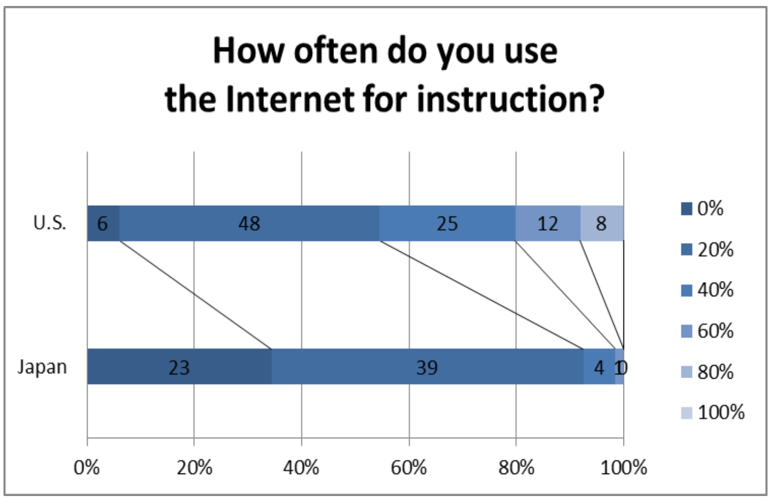

Figure 4. Frequency of Internet use

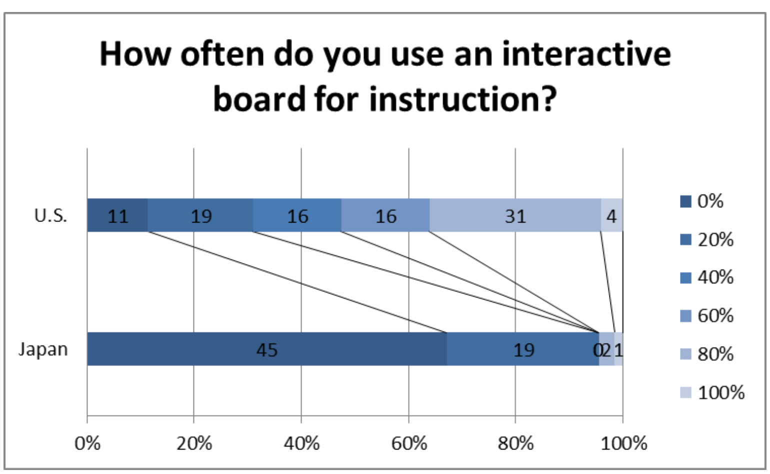

Figure 5. Frequency of Interactive board use

With regard to the frequency of technology usage, the differences were also significant. While 28% of the U.S. participants used a computer for 80% of their instructional time, only 3% of the Japanese participants used a computer as often for instruction. Nearly half of the U.S. participants used the Internet for more than 40% of their instructional time, but only 7% of the Japanese participants used it as much. Furthermore, about 67% of the U.S. participants used interactive boards at least 40% of their class time, whereas only 5% of the Japanese participants used interactive boards as often.

Predictors of PEUU, PU, and AT

Multiple regressions were used to investigate to what extent teachers' demographics and ICT environments explain the variability of PEUU, PU, and AT respectively (see Table 3). The regressions for PEUU showed that all variables together explained 18.3% of the variance for the U.S. (R^2=.183, F(6, 90)=3.37, p=.005) and 22% for Japan (R^2=.22, F(6, 60)=2.82, p=.018). The coefficients of independent variables suggested that the U.S. teacher's age significantly predicted the PEUU (β=-.29, p=.003), which means age is inversely proportional to PEUU, as did the number of computers in class in the U.S. (β=.11, p=.048), which means the number of computers in class is directly proportional to PEUU. In Japan, gender was a significant predictor for PEUU (β=-.49, p=.033).

No significant results for PU and AT were found in the U.S. However, in Japan, gender (β=-.46, p=.039) and the use of interactive boards in class (β=-.76, p=.021) were identified as strong predictors for PU. The existence of interactive boards in class affects positively on PU in Japan. The regression also revealed that all variables together significantly explained 27.8% of the variance in AT for the Japanese participants (R^2=.278, F(6, 60)=3.85, p=.003). In addition, gender (β=-.57, p=.039), interactive boards in class (β=-.104, p=.01), and the number of computers in lab (β=.68, p=.007) were identified as significant predictors for the Japanese participants' AT.

Table 3. Regression: Predictors of PEUU, PU, and AT

	PEUU		PU		AT	
Independent V.	U.S.	JP	U.S.	JP	U.S.	JP
Gender (Male=1, Female =2)	-.31	-.49*	-.31	-.46*	.01	-.57*
Age	-.29**	-.20	-.10	.11	-.12	.05
Teaching Experience	.08	.22	.10	-.18	.05	-.08
Interactive Board in Class	-.05	-.44	-.16	-.76*	.05	-1.04*
Number of Computer in Class	.11*	.34	.10	-.13	.07	.11
Number of Computer in Lab	.03	.01	-.08	.16	-.11	.68**
R^2	.18*	.22*	.07	.16	.07	.28*

*p<.05 **p<.01 βwere reported by unstandardized coefficients.

Predictors of Technology Usage

The regressions for the frequency of technology use also showed some significant results (see Table 4). PEUU, PU, and AT all together explained 18% of the variance in the use of computer in the U.S. (R^2=.186, $F(3, 95)$=7.23, p=.00), as did 21.5% in Japan (R^2=.215, $F(3, 63)$=5.75, p=.002). In the U.S., PEUU was the single best predictor for the use of computer (β=.63, p=.002), while AT was found to be a strong predictor for the computer use among Japanese participants (β=.31, p=.034). In Japan, PEUU, PU and AT all together significantly explained 14% of the variance in the use of the Internet (R^2=.142, $F(3, 63)$=3.47, p=.021).

Table 4. Regression: Predictors of Frequency of Technology Use in Classroom Instruction

	Computer Use		Internet Use		Interactive Board	
Independent V.	U.S.	JP	U.S.	JP	U.S.	JP
PEUU	.63**	.18	.25	-.00	.41	.02
PU	.11	-.03	-.09	.04	-.32	.12
AT	-.07	.31*	-.20	.19	-.53	.13
R^2	.19**	.22**	.06	.14*	.07	.07

*p<.05 **p<.01 βwere reported by unstandardized coefficients.

Discussion

The purpose of the present study is a cross-cultural comparison between the United States and Japan in order to identify factors that affect the attitudes of teachers towards the use of technology in the classroom.

Comparison by chi-square contingency analyses of the ICT environment and the frequency of ICT use showed that overall the U.S. teachers had more access to the ICT in classroom and use them more often for instruction than the Japanese teachers. These results were consistent with the past research conducted in 2009 in the United States by the National Center for Education Statistics and the MEXT study conducted in Japan in 2011.

One notable finding about demographic data is that the Japanese teachers' gender significantly predicted PEUU, PU, and AT, while the U.S. teachers' gender did not. This may be because of the different proportions of gender in elementary school between Japan and the U.S. The majority of the U.S. teachers were female, but the Japanese teachers were almost equally distributed among female and male. The slope of the regression also indicated that the male teachers better predict PEUU, PU, and AT in both countries, even though the U.S. data did not show significant results. Another finding is that the U.S. teachers' age significantly predicted PEUU. The negative slopes of the regression clarified that the younger age predicted more positive PEUU, suggesting that even in the U.S. there seems to be a generation gap between teachers brought up in technology-rich environment and pre-technology time. This finding supports the study by Inan (Inan & Lowther, 2010) in that teacher's age negatively affects computer proficiency and computer integration.

Regarding the ICT environment in schools, whether the teacher had an interactive board in class significantly predicted PU and AT among the Japanese teachers, whereas with the U.S. teachers it did not show a significant difference. This reflects the fact that newly introduced technology can affect teachers' attitude toward ICT. (Japan has just introduced one interactive board in each elementary school.) It has been also shown that PEUU in the U.S. and AT in Japan significantly predicted the frequency of computer use in class. However, the causal relationship between the school systems regarding the technology environment and the teachers' attitude toward technology use cannot be drawn from the present analysis. Also, teachers with more favorable attitude toward the use of technology encourage the school to have more technology access. Meanwhile, it is possible for the Japanese teachers to respond negatively to the use of technology regardless of the quality of ICT environments in school as the past studies suggest. Japanese teachers' negative beliefs toward ICT learning may be due to the lack of information about the research in the field of early childhood education (Joshi et al., 2010). Further research should explore the causal connection between the quality of technology environments and the teachers' attitudes, beliefs, and the possible improvements in the classroom on cross-cultural comparisons as well as the domestic comparisons.

Limitations

The current study measured the use of many types of ICT aids that can be utilized in the classroom such as interactive whiteboards, iPads, computers, and internet use. In comparison, many other studies evaluate the use of only one type of technology. This limitation may give an inconsistent result if some teachers prefer certain types of technology over another.

Another limitation was the gender differences and number of surveys collected between the two countries. In the United States, female elementary school teachers outnumbered the male elementary teachers to a large degree, yet in Japan, the number of female to male teachers was almost equal. Diversity of the curriculum in the U.S. education is a challenging factor to the sampling equivalence in cross-cultural comparison. Defining the appropriate representative of the U.S. culture is another issue that future studies could focus on for methodology design.

Conclusion

The results of the current study suggest that when schools and teachers have greater access to technological resources in the classroom, attitudes of teachers are more positive towards the use of technology and they tend to use technology to a greater degree as they educate their students. This may place Japanese students in a disadvantage compared to American students as they prepare to enter and compete in a global society.

In the present study, the population sample that responded to the surveys in both Japan and the United States came from rural regions. Future research should collect a larger population sample including a broader range of respondents from both urban and rural areas. In addition, the factors influencing Japan's lack of technological resources in public education are unclear. Therefore, future research should investigate the influences that determine Japan's lack of technological accessibility in the public education system.

Numerous recent studies have established the benefits of technology use and efficacy within the elementary classroom in preparing students for their future in a global society. The attitude of the educator towards technology use in the classroom is indicative of how well technology will be integrated in the classroom during instruction. Follow-up studies on this regard across cultures are necessary in order to find better approaches for teachers and state administrators in this rapidly changing globalized age.

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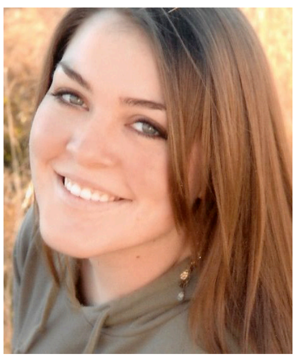
Biographies

Kodai Kusano is currently a senior student at Southern Utah University, majoring psychology and physical education. He has been interested in cross-cultural research since his experience as an international student at SUU changed his outlook. He is now planning to pursue a doctorate degree in social/cognitive psychology with emphasis on cultural psychology. His research interest focuses on decision-making process among collectivistic and individualistic cultures. His career goal is to broaden not only his own perspective, but also to broaden other people's minds by studying reciprocal interaction between culture and human behavior on a variety of domains in this global society.

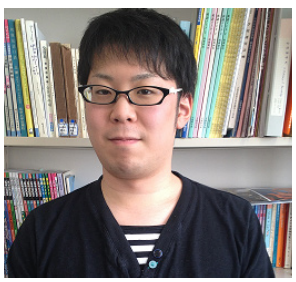


Sarah Frederiksen is currently a senior attending Southern Utah University. She is majoring in Elementary Education with an emphasis in English as a Second Language. This is her first undergraduate research completed. She strives to learn all she can about successful teaching strategies and effective instruction for students. Her research interests are driven by the curiosity to know how technology can be better utilized within a classroom setting to benefit students of all ages and languages.

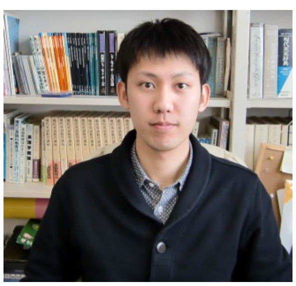
LeAnne Jones is a non-traditional student at Southern Utah University, set to graduate with her BS in Elementary Education with English as a Second Language Endorsement. She volunteered for nine years and then became employed at a local elementary school as she raised her young children. Her experiences working with children in the public education system led her to pursue her dream of becoming an elementary teacher. She has a great interest in improving the educational opportunities of children by using all available resources, including technology use in the classroom.

Michiko Kobayashi is Assistant Professor of Education and Associate Director of Center of Excellence for Teaching and Learning at Southern Utah University. She holds MS in Linguistics & English as a Second Language and PhD in Instructional Design & Technology. Her specializations include distance education, technology integration in the classroom, second language acquisition, and multicultural education. Dr. Kobayashi has been involved in distance education programs at different grade levels. In addition to teaching pre-service and in-service teachers, she also provides online pedagogy workshops for faculty. Her current research focuses on the development of student's cultural consciousness using Web 2.0 technologies.

Yui Mukoyama is a graduate student at Hokkaido University of Education, Asahikawa campus. Her major is English education. She studies second language acquisition in order to be an English teacher in junior high school. She has an interest in how to improve English speaking skills. She made a presentation in Pacific Rim 2012 held in Japan.



Taku Yamagishi is a graduate student at Hokkaido University of Education, Asahikawa Campus. His major is English education. His interest includes ICT, in particular, computer assisted language learning. In his past research, he focused on the essential elements in English e-Learning systems and constructed an optimal system to examine the elements. He made presentations in Pacific Rim 2012 held in Japan and e-Learn 2012 in Montreal.



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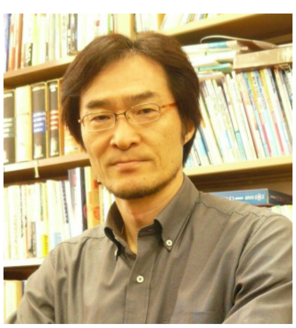

Hiroki Ishizuka is Professor in the Department of Education at Hokkaido University of Education (HUE). He obtained his Master's degree in HUE, and finished Ph.D. course in the Department of Information Science at Hokkaido University. His research interests include language education in 3D virtual reality, technology use in language class, e-Learning system, and second language acquisition. His research work is published in leading journals including ELEED (E-Learning and Education) and JASELE Journal. His published books include an authorized junior high school English textbook and a manual of information education in secondary school. He worked as a member of the editorial board for JASELE Journal and JACET Bulletin.

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Presenting an Alternative Source Code Plagiarism Detection Framework for Improving the Teaching and Learning of Programming

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Abstract

The transfer and teaching of programming and programming related skills has become, increasingly difficult on an undergraduate level over the past years. This is partially due to the number of programming languages available as well as access to readily available source code over the Web. Source code plagiarism is common practice amongst many undergraduate students. This practice has a detrimental effect on the presentation of specific content relating to introduction to programming courses. One of the problems identified in the research conducted is that turn-around time with relation to assessment and feedback, which are presented to the students, is a critical factor in the subsequent success rates of the subject.

This paper investigates, utilizing a literature review, how plagiarism detection metrics and a framework for providing effective feedback to students and educators could be implemented to enhance the teaching and learning processes.

The predominant technique used for detecting plagiarism is to evaluate how a piece of source code was constructed over time. By analyzing the students' programming patterns, lectures can be adapted to address problem areas and react accordingly. The paper also provides an overview of current metrics used for plagiarism detection and suggests ways of improving the process by including enhanced techniques for the gathering of metrics over time as well as suggesting ways to use the metrics to aid learning on all cognitive levels.

Some of the key considerations presented as part of this research include effective feedback mechanisms and real-time responses to plagiarism as well as contributing towards learning on different cognitive levels.

Keywords: Blooms digital taxonomy, Plagiarism detection, Teaching Programming, Teaching methodologies.

Editor: Peter Blakey

Introduction, Background Problem and Prior Research

The positive effects of the digital revolution are offset by the negative impact it is having on academic institutions. As the digital age is evolving, thereby increasing student access to information, it is becoming more difficult for academic institutions to maintain academic integrity across instructional programs.

This paper utilize a combination of a literature review and the creation of a framework that aims at addressing some of the core issues identified as part of the literature survey, as well as reflections and insights provided by academia and colleges.

Zobel (2004, p. 147) emphasizes the fact that a literature study should contribute text in providing the reader with a better understanding of the elements of the study as well as the topic researched. He explained that in an ideal research document the literature study should be as interesting and thorough as the description of the paper's contribution.

Some of the benefits of a literature study, as listed by Leedy and Ormond (2004, p. 70), will greatly contribute to the understanding and implementation of the research objectives, the relevant benefits are:

- The capability of such a study to reveal approaches followed by other researchers in the same area or field.
- Show and introduce some relevant measurement tools developed in previous studies of a similar nature.
- Revealing methods of dealing with problem situations that may be similar in nature to the current research study.

As can be derived from the benefits, a literature study will play a key role in this study to be done, both from an informative and active learning point of view.

Plagiarism, as defined by Merriam Webster ("Plagiarism," 2012), is "the act of using another person's words or ideas without giving credit to that person." The threat of plagiarism is not only limited to academic writing, but also includes source code that is written as part of the learning process.

In addition to verbatim copying of assignments between students, a programming assignment may also be considered plagiarized if the code was converted directly from another programming language, if code is reused between assignments (self plagiarizing), if students collaborate extensively when writing code, or when other people are paid to write code (Joy, Cosma, Yau, & Sinclair, 2011).

There are numerous examples of websites and services that host searchable code which is accessible by the public, e.g., question and answer sites that provide ready-made solutions to programming problems and websites where, for a relatively small fee, a programmer can be hired to complete a task. This provides enough resources to tempt a student into plagiarizing part of, or an entire, assignment. The Internet should not carry all the blame for the prevalence of student plagiarism (Cosma & Joy, 2008).

A study done by Lim and See (2001) involving data collected from three educational institutions in Singapore showed that about 94% of students admitted allowing their own work to be copied by other students. A similar study in Australia involving first year students found that those participating in the study thought that it was acceptable to collaborate on assignments that were meant to be completed individually (Sheard, Dick, Markham, Macdonald, & Walsh, 2002).

Current Source Code Plagiarism Detection and Prevention Techniques

Methods for dealing with the problem of plagiarism can be classified based on approach followed, i.e., ‘proactive’ methods for preventing plagiarism from taking place and ‘reactive’ methods of detecting plagiarism after work has been completed and submitted (Lukashenko, Graudina, & Grundspenkis, 2007).

Recent proactive methods used by academic institutions are educating students on plagiarism, creating clear anti-plagiarism policies across different academic programs, and adopting honor codes (Devlin, 2006; Olt, 2002; Park, 2003).

Reactive methods used for plagiarism detection in source code are widely considered to be a pattern-matching problem which produces a number of metrics. The metrics can then be analyzed to determine how much of the source code was copied between different documents in the corpus that is being evaluated (Jones, 2001). Lancaster and Culwin (2005, p. 4) define a ‘metric’ as a rule that can convert a document into a numeric value for representing similarity.

Traditional Detection Approaches

sA common approach to plagiarism detection in source code relies on parsing the source code contained in the document and then generating token strings. Using an algorithm, the token strings generated by this approach are, then, compared to other token strings. The Sim utility is an example of the approach. It uses string alignment techniques and algorithms originally developed to detect similarity between DNA strings (Gitchell & Tran, 1999). An alternative method also relies on tokenization, but determines similarity by analyzing the structure of the source code.

Whale (1990) has argued that better results can be achieved by analyzing source code structure, and has supported these arguments by developing a utility called ‘Plague’. Wise (1992) identified some problems with Plague, but supports the notion of analyzing structure similarities as opposed to text similarities.

The deterrent posed by effective plagiarism detection engines provides the only link between proactive and reactive methods. Implementing proactive methods to prevent plagiarism may require more time to implement, but it may produce a positive effect in the longer term (Lukashenko et al., 2007). Howard (2002) notes how the amount of effort used in detecting academic plagiarism may result in students seeing the educator as the enemy instead of the mentor. Blindly using detection tools gives no insight into the student’s reasons for plagiarizing. The researchers believe that the notion of Howard (2002) opens the door to try and find ways in which the detection practice could also improve the teaching and learning process, and not just act as a deterrent.

It would seem that proactive and reactive methods for dealing with plagiarism are not well aligned. Reactive methods provide instant results that show whether a piece of source code was plagiarized or not. The researchers, however, stress that, in the long term, this method may not add much value to the academic process leading to students focusing on ways to defeat the engine. In contrast, the proactive approach may provide positive results in the long term. It should be noted, that the proactive methods still do not produce immediate results that can be used to verify originality of code.

Figure 1 indicates the traditional workflow of how a student may complete and submit a programming assignment. In this traditional workflow, only the final document, or documents, (containing the code) are submitted to the detection engine. The engine then analyses the documents in the corpus and feedback is provided to the educator for further analysis. The student is notified after the educator has interpreted the results on whether the submission is considered plagiarized on or not.

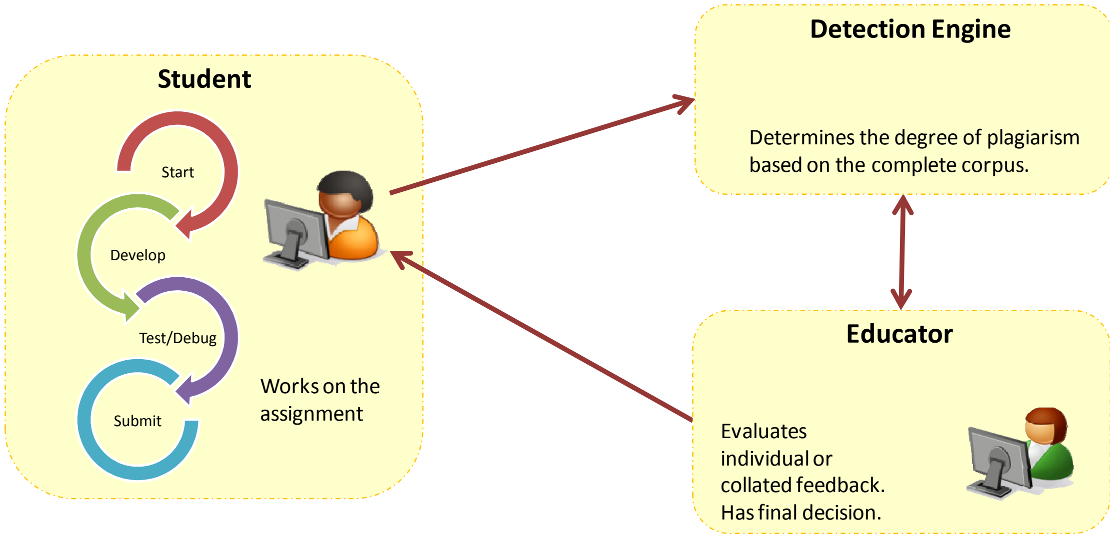

Figure 1: Workflow followed in traditional detection engines

One problem identified with the workflow described above is that the history of how the student created the piece of source code is lost. Students code and develop software in different ways. Due to the nature of programming, and the inclusion of various code constructs and units in the development of a solution, the authors believe that it is important to track and monitor the complete development process rather than just the final product. Because there is no time-line of how the source code was constructed, any direct evidence that the student used to try to conceal plagiarism is also lost.

There are various reasons for students plagiarizing a piece of source code including:

- Lack of technical knowledge
- Self-plagiarising or plagiarising commonly repeated functionality
- Poor time management
- Academic pressure

Power (2009) concluded that students often don't understand what is considered plagiarism. According to Voelker, Love, and Pentina. (2012) a similarity exists regarding how both graduate and undergraduate students understand plagiarism. This suggests that students' lack of understanding about plagiarism is not strongly correlated to a certain level of education. Voelker et al. (2012) go on to mention the way in which many students think plagiarism can be avoided by citation and reference alone.

The problem of plagiarism due to a lack of understanding can be interpreted differently when the task is to write a piece of source code. When writing source code as opposed to writing academic work, there is no generally acceptable rules regarding citing and reference.

The task is to solve a specific problem writing a number of statements in a logical sequence using the syntax of a specific programming language. The lack of understanding in this case may be an inability to use this specific language and its syntax to solve the problem at hand. The student may not have sufficient knowledge of the language or syntax to solve the given problem in the first place. As a result and sometimes a last effort students may revert to plagiarism.

A programming problem can also be solved using code by breaking the problem up into a number of small sub-problems. When unable to solve one of these smaller problems, a student may revert to plagiarism while still being able to solve other sub-problems. In the process of combining the smaller problems, the student may learn what the purpose of the plagiarized code is and how the code works. A student may also use a piece of code that was previously written and well understood to solve a sub-problem.

Students may feel they have not been given enough time to complete an assignment or may generally procrastinate leading to time pressures (Power, 2009). Koul, Clariana, Jitgarun, and Songsriwittaya (2009) concluded that performance oriented students are more likely to plagiarize. This may be due to pressure to from society, family or educators to obtain good grades (Devlin & Gray, 2007).

Two other factors that might influence the decision to plagiarize are the consequences of getting caught and how uniformly plagiarism detection techniques are enforced across different subjects (Miller, Shoptaugh, & Wooldridge, 2011; Power, 2009). Other possible reasons for plagiarizing include personal and cultural attitudes towards plagiarism and the desire to test the system (Wan, Md Nordin, Halib, & Ghazali, 2011).

Using traditional detection engines gives no indication of the student's motives or underlying academic reason for plagiarizing. Another academic reason which could motivate a student to plagiarize is the fact that the student had a difficult time in interpreting and understanding a lecture presented by an educator, based on a certain topic. Language barriers could also have an impact on the student's motivation. The metrics used to detect the plagiarism are of no further use once it has been determined that a student has plagiarized.

Defining a new set of metrics that provide indications of both that a piece of source code has been plagiarized and why its creator plagiarized may be beneficial to both the student and educator.

Plagiarism Detection Engine Based On New Metrics

To determine when source code plagiarism occurred, as well as the possible reason(s) for the plagiarism, a detection engine needs to be developed that may track the source code being written by students in real time. The engine may then produce the required metrics to guide the educator in identifying plagiarism while adding value to the academic process.

Evens and Peck (2006) have suggested that the use of light weight analysis may enhance teaching software engineering. By introducing the concepts in a pilot course to test the assumptions made by the researchers, students were asked to record the time spent on each programming assignment. Jones (2001) attempted to use physical metrics – namely number of lines, words, and characters. Further detection relied on the source code, the compilation log, and the execution log.

It should be noted that both of the above approaches only consider source code after submission. In addition, no detection of plagiarism is attempted as the code is being written. Metrics to identify plagiarism of source code, as it is being written include:

- Time spent writing code for the assignment.
- Number of modifications, including the text that was modified each time.
- Length of each modification that was made.

Tracking the time that a student spent writing code for the assignment may be the first indication of possible plagiarism. This metric may also give a unique insight on the student's time management skills as well as insights on how assignments are completed, and in addition, may indicate the possibility of the student having plagiarized some or all of the code in the assignment. This may be evident especially if there is a big discrepancy between how long the educator expects the student to work on the assignment and the actual time to completion.

Tracking the number of modifications over time may point to possible plagiarism or plagiarism avoidance. This is especially true if the student adds a large number or lines to the code base and then proceeds to make a number of small changes over time. Tracking the text that was inserted or deleted can aid the educator in determining whether the motive for the number of changes was to avoid plagiarism detection or to integrate code that was previously written to solve a similar problem. If data is collected from multiple students with multiple attempts, patterns could be identified and used by the educator to design or to modify future lectures.

Finally, the length of each modification can be used to detect both plagiarism and plagiarism avoidance. When using these metrics, the problem of detecting extra-corpal plagiarism – like sources from the web and textbooks – is largely made irrelevant by the fact that the engine does not need these source documents when analyzing the corpus instead making a deduction based on the metrics mentioned above.

Figure 2 shows an updated workflow, which may support the effort to gather the new metrics identified. This workflow consists of the Code Snapshot Service (CSS), Notification Service (NS), and the Plagiarism Detection Tool (PDT). The student may work on the programming assignment while the CSS takes regular snapshots of the code that is being written. Each snapshot may contain the code for the assignment as it was during the particular time that the snapshot was taken. These snapshots are delivered to the PDT that continuously analyses new snapshots as they arrive.

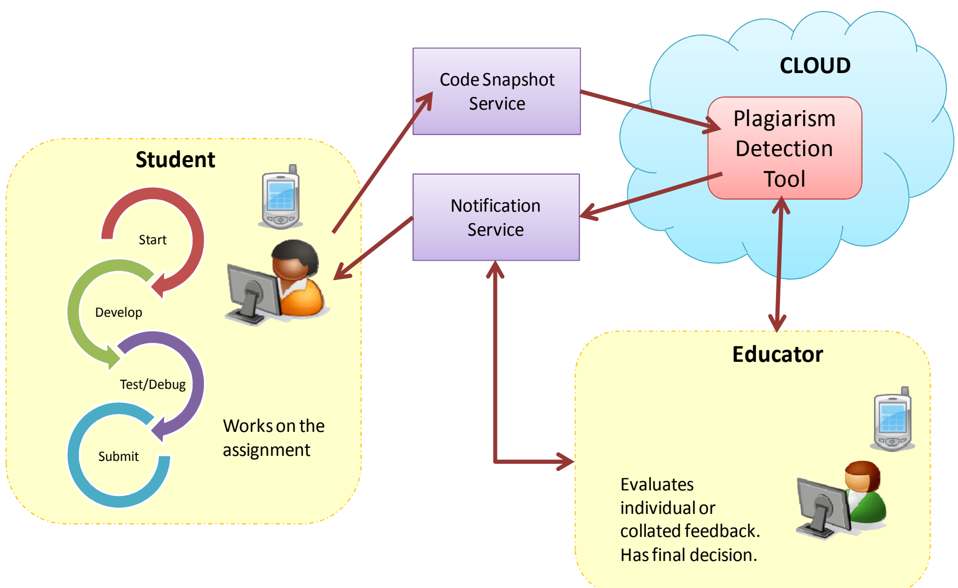

Figure 2: Workflow to support metrics identified

To generate the metric that indicates time spent on writing code for the assignment the time difference between when the first snapshot and last snapshot were received may be used. The number of modifications and the text that was modified may be determined by comparing the source code of successive snapshots. Each snapshot taken over time may also indicate the length of the addition which has significant value in the detection process.

Because the PDT does not compare different assignments in the corpus with each other, but rather analyzes the snapshots based on the new metrics (e.g., time spent on writing code, number of modifications including the text that was modified, and the length of each modification), the tool does not need to wait for all documents to be present in the corpus before analyzing for possible plagiarism.

The notification service may be responsible for notifying students about the determination the PDT makes in real time. In contrast to traditional detection engines, the proposed method allows the student to be notified that the PDT has determined that possible plagiarism is occurring, while the student still has time to take corrective action.

After the student submits the final version of the assignment, the NS notifies the educator, who may use all the metrics gained by the PDT to make a final determination in each case.

In addition to being used to detect whether plagiarism has occurred, the new metrics gained from the PDT can provide clues on why the code was plagiarized.

Enhancing Teaching and Learning by Providing Possible Reasons for Plagiarism

Figure 3 shows how the metrics gained from the PDT can be used by the educator to identify possible reasons for why a student plagiarized a programming assignment. As the metrics are gathered by the PDT they are analyzed by the educator to identify the possible reason for plagiarism. Either a single metric or a combination of metrics may be used to identify the reason for plagiarism.

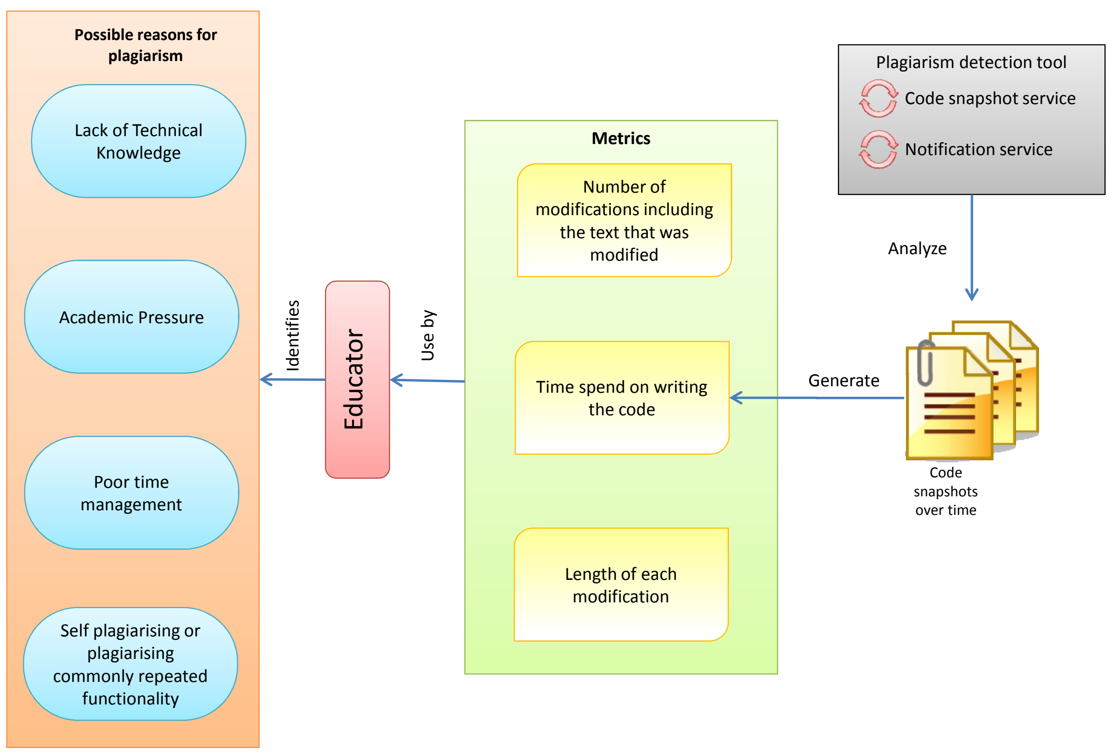

Figure 3: Metrics gathered by PDT to indicate possible reasons for plagiarism

First, a lack of technical knowledge can be identified by looking at the number of modifications including the text that was modified in each successive snapshot. If the code that was inserted in each successive snapshot varies widely between snapshots, it may indicate that the student is attempting to fit code to the situation blindly and hoping to find a possible solution. Further analysis of the text that was modified can be compared to publicly available code repositories to pinpoint the sources that the student consulted in order to find the solution. This behavior may also point to academic pressure as a possible reason for plagiarism. If a large change occurs between snapshots, and if the code that is changed between successive snapshots shows that both snapshots solve the same problem in a different way, the student may have found code which, in the student's mind, may get a better academic result then the original code written by the student.

Second, poor time management can be identified by looking at the time spent on writing the code. Since the PDT receives regular snapshots while the assignment is being completed, the total time spent should be relatively accurate by considering when the first and last snapshots were received. Successive snapshots with no code difference can be ignored. By combining information regarding the number of modifications including the text that was modified and the time spent on writing code, it is possible to detect students that have added a large number of lines to their code base close to the submission deadline. This indicates that possible plagiarism because of time constraints has occurred. Combining the metric for all submissions may also provide an average time of completion for all students and can be compared to previous assignments with the same level of difficulty by the educator.

Third, self-plagiarizing, or plagiarizing commonly repeated functionality, can be identified by detecting that a student has inserted many lines of code at once and then proceeded to make many small changes. This activity can be detected when a snapshot reveals that a large amount of code has been inserted, and then subsequent snapshots reveal only minor changes being made. This may likely indicate that the student is using code previously written and is adapting the code to fit a given problem. By analyzing the code that was inserted and deleted in each successive snapshot, it is possible to determine whether the small changes the student made were due to self-plagiarism or whether the student made those changes in an attempt to avoid plagiarism detection.

Because an educator may make the final determination as to whether plagiarism has occurred only after all final submissions have been received and reviewed, students can be warned in real-time as the assignment is being completed that they run the risk of plagiarizing their assignments. This real-time feedback provides a more proactive approach to detecting plagiarism than the reactive approach followed by current detection engines. In addition, the proposed method can enhance teaching and learning as the student completes the programming assignment.

Using Plagiarism Detection Tools to Provide Feedback to Students in Real-Time

As part of the student learning through effective feedback project, Juwah et al. (2004) have identified seven principles of good feedback practice in academic environments. According to the reasearchers' view, a good feedback practice is one that:

1. Facilitates the development of self-assessment in learning.
2. Encourages teacher and peer dialog around learning.
3. Helps clarify what good performance is.
4. Provides opportunities to close the gap between current and desired performances.
5. Delivers high quality information to students about their learning.
6. Encourages positive motivational beliefs and self esteem.
7. Provides information that can be used to help shape the teaching.

The authors have also developed a conceptual model for information feedback. This 'formative assessment and feedback model' is based on a model developed by Butler and Winne (1995). The biggest problem the originally proposed model aims to address is the problem that feedback is usually only available after a learning activity has been completed. In the adapted model the student is placed in a central role regarding the feedback process. The student and educator are at all times actively involved in monitoring and regulating the goals as set out by the educator. Figure 4 shows how the PDT can be incorporated into the formative assessment and feedback model.

A learning activity like a programming assignment may start with the educator providing the criteria and other goals that should be accomplished by the student. From there, most activities take part as part of the internal student process.

The student may start by studying the provided goals and criteria and may draw on previous domain knowledge to develop a number of personal goals to be achieved while completing the assignment. The next stage involves the student applying a number of tactics and strategies to complete the assignment, or part of the assignment, by producing a learning outcome. In this case the learning outcome may be a document(s) containing source code.

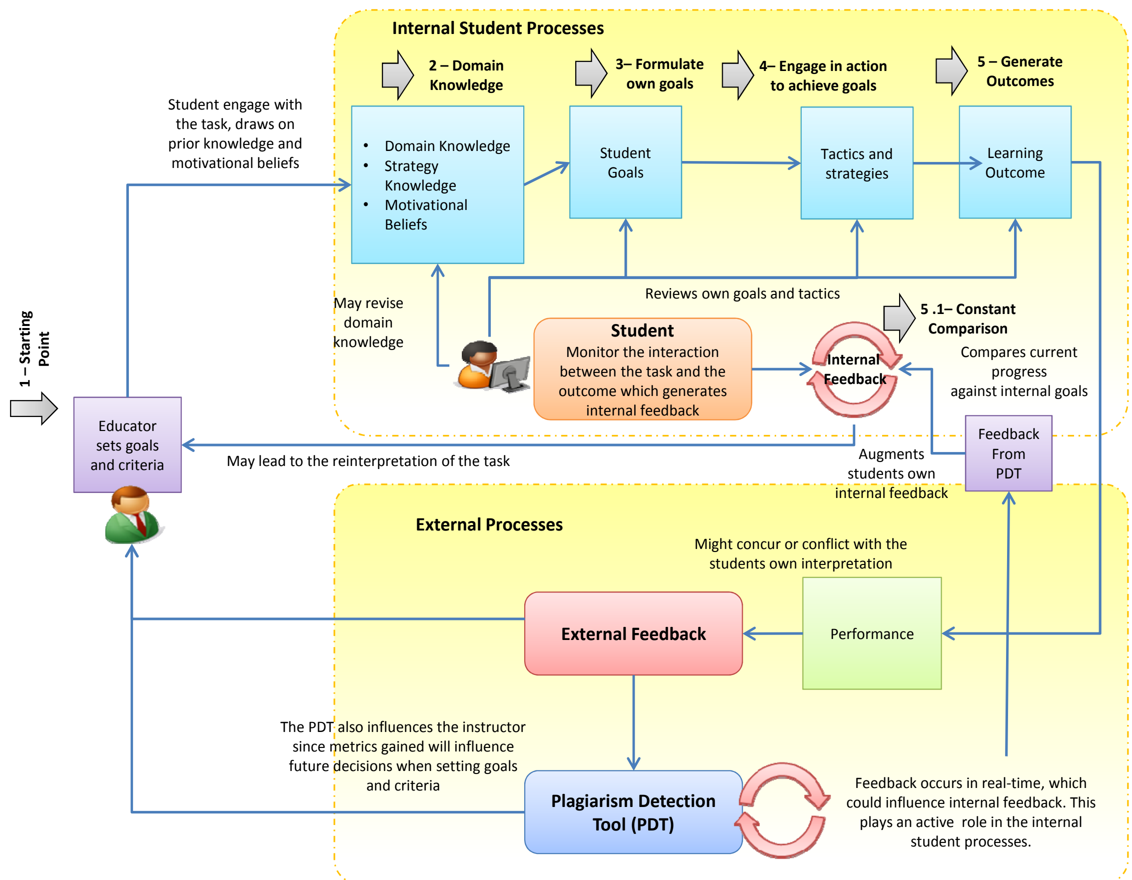

Figure 4: Incorporating the PDT into the formative assessment feedback model

The process of writing the source code for the assignment may be influenced by internal feedback. This feedback may be generated by the student on a continuous basis. This may lead to the student re-assessing personal goals. It may even lead to the student revising and updating existing domain knowledge which stimulates cognitive development. This internal feedback is continuously augmented by the PDT via the Notification Service (NS) based on results from analyzing the code provided by the Code Snapshot Service (CSS).

As part of the external processes, the student's performance is measured and feedback is provided by an external entity. Usually, this external feedback occurs only after a learning outcome is achieved. The new knowledge gained from the external feedback is only used and tested by the student during the next learning activity, whilst some academic value is lost in the current instance.

Because the PDT may provide students with feedback in real time, the external feedback processes can play an active role in the students' own internal feedback and learning process. The feedback generated by the PDT can also influence the educator. In addition to being useful for detecting plagiarism, the metrics gained by the tool may influence an educator's decisions regarding the goals and criteria for future programming assignments. It may also impact and highlight certain areas in the curriculum which needs additional modifications in instruction. The metrics, and the way that they are being gathered, may also allow for different types of programming assignments to be used when assessing students.

Plagiarism Detection Tool to Aid Learning on All Cognitive Levels

Buck and Stucki (2000) argue strongly that teaching computer programming should start at a low cognitive level and slowly progress to a higher level. This approach of moving from a lower level to a higher level often relies on Bloom's taxonomy of cognitive learning (or on the revised digital version thereof (cf. Churches, 2009)) for its structure.

Bloom's revised taxonomy follows the process of learning through a number of categories, starting with lower order thinking skills and progressing to higher order thinking skills. Unlike Bloom's original taxonomy, the revised taxonomy names each category by using a verb. Beginning with the lowest order, marked by the name *remembering*, the revised taxonomy progresses through categories named with the verbs *understanding*, *applying*, *analyzing*, and *evaluating*. The taxonomy ends with the highest order thinking skill being named *creating*. As a learning process, Bloom essentially requires a concept to be remembered before it can be understood. Once understood, the concept can be applied and then analyzed to evaluate the impact. It is only after all the other categories have been adhered to that creation can take place (Churches, 2009; Krathwohl, 2002).

A plagiarism detection tool that provides real time feedback with metrics indicating how the code was constructed can help educators evaluate and ensure the academic reliability of different assessment methods and strategies beyond those requiring students to write complete programs. Some of these alternative assessment methods may include the use of skeleton programs, code inspection, and self-assessment.

Lister (2000) describes an alternate approach to letting students write complete programs as soon as possible in the academic calendar year. That approach concentrates on the first four levels of Bloom's taxonomy; namely *remembering*, *understanding*, *applying*, and *analyzing*. Multiple-choice questions were used in combination with the completion of skeleton programs where only a skeleton is provided and the students should complete the program by writing lines of code that had been left out of a complete program. Lister argues that skeleton programs teach students good programming practice and guide their thinking into a productive learning pattern.

Using traditional plagiarism detection engines that rely on comparing text may be problematic in skeleton programs. This is because the code submitted may not vary significantly between students. In addition the code may consist of a number of small changes to the original program. In contrast, with the PDT the educator can evaluate the time spent on writing the code and what changes were made between each successive snapshot. If the snapshots are made in quick enough succession they should give a good indication of how given code was inserted to complete the skeleton.

McMeekin, von Konsky, Chang, and Cooper (2009) conducted a pilot study that required undergraduate students to inspect code. The authors concluded that code inspections can lead to students developing higher cognitive levels. Alaoutinen and Smolander (2010) noted how a goal-oriented learning environment can motivate students and result in meaningful learning. The authors go on to say that this goal-oriented environment can be created by involving self-assessment in the teaching process, but self-assessment is often disregarded because of reliability issues. We believe that combining self-assessment with code inspection while maintaining reliability may be made possible by the implementation of the PDT.

Using the PDT the educator can provide students with some code to inspect and to comment on. Using the metric gained by the PDT (e.g., time spent on writing code, number of modifications including the text that modified, and the length of each modification), the educator can assess how students interpreted the code. This has great teaching value for both the educator as well as the students.

Since the PDT gives a complete overview on how code was constructed line by line, the successive snapshots and the differences between the snapshots can be used by a student to not only assess his or hers own work but also the work of other students.

The authors believe that the utilization of the PDT could aid in the presentation of programming, by allowing process to evaluate student’s performance on assessments, based on each of the digital taxonomy levels as presented by Churches, (2009).

Conclusion

Literature suggests that plagiarism remains an active and ongoing problem and threat to academic institutions. Reactive and proactive methods of plagiarism prevention and detection do not align and complement each other. In traditional source code plagiarism detection engines that consider plagiarism detection a pattern matching problem, no indication is given on the reason for the student choosing to plagiarize. The proposed implementation of detecting plagiarism by utilizing metrics gained over time which is reported in real-time aims to improve the link between proactive and re-active methods of plagiarism detection.

The formative assessment and feedback model presented as part of this paper aims to limit the practice of plagiarism by providing real-time feedback to the student as well as the educator. This process could act as a deterrent for the practice as well as enhance the learning processes of the individual student. By incorporating real time feedback the student is proactively warned of possible plagiarism infringement and can correct the situation. The educator will still have the final say on a case by case basis maintaining the ability to reactively respond to plagiarism.

The next phase of this research is addressing the issues identified in the literature review by the creation of a prototype based on the PDT framework. Research needs to be conducted on how best to implement the PDT and the associated services. Once the PDT prototype is created experiments can be conducted to investigate if the method of plagiarism detection presented in this paper acts as an effective plagiarism deterrent.

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Advancing Creative Visual Thinking with Constructive Function-based Modelling

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Executive Summary

Modern education technologies are destined to reflect the realities of a modern digital age. The juxtaposition of real and synthetic (computer-generated) worlds as well as a greater emphasis on visual dimension are especially important characteristics that have to be taken into account in learning and teaching. We describe the ways in which an approach to constructive shape modelling can be used to advancing creative visual thinking in artistic and technical education. This approach assumes the use of a simple programming language or interactive software tools for creating a shape model, generating its images, and finally fabricating a real object of that model. It can be considered an educational technology suitable not only for children and students but also for researchers, artists, and designers. The corresponding modelling language and software tools are being developed within an international HyperFun Project. These tools are easy to use by students of different age, specialization and abilities, and can easily be extended and adapted for various educational purposes in different areas.

We applied the theoretical framework and software tools at different levels of education starting from elementary schools to doctoral thesis research in various areas related to artistic design and animation, computer graphics, programming languages, software development, and experimental and theoretical physics. In the process, the students learn how rather abstract mathematical expressions result in creating visually and meaningfully appealing computer-generated artefacts of a different nature that can eventually be fabricated as real objects using 3D printing means. Several application case studies in various areas of art, design, and technical education from different educational institutions and countries are presented. The obtained practical experience shows that this approach can be mastered and appreciated by students at different levels of education as an activity stimulating and supporting their creative thinking. The social context of the learning process allowing for collaborative work is also worth of noting. The presented case-studies demonstrate

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that seemingly complex modern means of geometric modelling and fabrication can easily be mastered not only by students oriented toward computer specialties but also by children (including those with disabilities) and artists.

Keywords: Interactive geometric modeling, Computer animation, Scientific visualization, 3D printing, Digital fabrication, Kinect, Function Representation FRep, HyperFun, Constructionism learning theory, Visual thinking.

Introduction

Visual thinking or human operating with mental images is strongly imbedded in modern culture through education, media, and entertainment. A new generation of educational technology is necessary with a particular emphasis on visual thinking to stimulate and facilitate creativity. Computer support of visual thinking remains on the ideology platform built more than 30 years ago. Computer graphics tools as the basis of this support were originally oriented to producing eye pleasing pictures. Nowadays real and synthetic worlds not only exist in parallel, but interact and interpenetrate each other. Examples of such interactions are areas such as 3D Face Recognition that performs automatic construction of an appropriate 3D model from a real face, Augmented Reality that suggests manipulating 3D objects through attached markers and combination of real time web camera view with 3D model in one imaginary scene, Digital Fabrication that brings 3D models to real world by 3D printing means, and modern cinematography techniques allowing to mix actors with synthetic characters generated by 3D computer animation means. This challenge has to be adequately addressed by new generation computer technologies, which require rethinking of the entire process ("pipeline") starting from real objects, their mental visualization and abstraction, mathematical description, computer representation, interactive manipulation with the model, generation of images, fabrication and utilization of new tangible objects thus creating augmented worlds. These worlds including real and virtual components can be experienced, explored, and modified.

Currently dominating geometric models in computer graphics are 2D vector graphics, 3D polygonal surfaces, and parametric surfaces. The problems with these models are well-known: non-precise shape and visual properties definitions, growing memory consumption, limited complexity, topological ambiguities, and others. Such a geometric representation was able to be handled by computers 30-40 years ago. Modern multiprocessor computers are able to deal with much more complex data structures and mathematical models, which were previously unimaginable.

The ability to process and the necessity for compact precise models with unlimited complexity have resulted in the development of the new paradigm of procedural modelling and rendering, where the object's geometric shape and properties are evaluated upon request using procedural rules. One of the approaches to procedural modelling is to evaluate a set of real functions (or a vector-function) representing the shape and other object properties at the given point. A constructive approach to the creation of such function evaluation procedures for geometric shapes was proposed and called the Function Representation (FRep) in Pasko, Adzhiev, Sourin, and Savchenko (1995) and then extended in Pasko, Adzhiev, Schmitt, and Schlick (2001) to the case of point attribute functions representing such object properties as material, colour, transparency, and others. The main purpose of this approach is the creation of complex models from simple building blocks using operations similar to a model assembly in LEGO (see the illustration in Figure 1). While the user operates on the high-level of abstraction, a modelling system maintains the final function evaluation procedure for the modeled object.

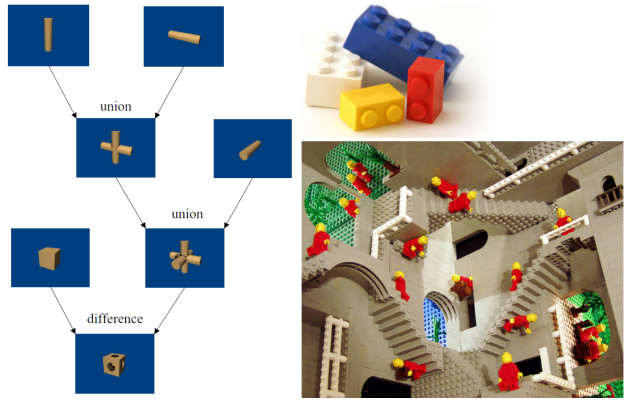


Figure 1: *Constructive tree structure reflecting the logic of the object assembly (left), simple LEGO building blocks-primitives (top right), and a LEGO model assembled from those primitives (bottom right.)* Source: nOmArch, 2009

It is worth noting that this approach corresponds to the constructionism learning theory introduced by Seymour Papert (Papert & Harel, 1991). Application of this theory using computer technologies in educational practice is not always easy (Beynon & Roe, 2004). It is well known that constructivist thinking is the basis of the LEGO construction toys which enable children to learn notions that were considered as too complex for them. We have been developing virtual modelling and graphics tools rather than physical ones providing an extendible set of "building blocks", which are deformable and modifiable on the fly. This approach assumes the model creation using a simple programming language or interactive tools with subsequent generation of its images, and finally fabricating a tangible replica of the created model. We believe that such an approach is of interest as an educational technology suitable not only for children and students, but also for researchers, artists, and designers. Earlier applications of this technology in education were reported in (Pasko & Adzhiev, 2009). In this paper, we would like to present further experience and case studies in various areas of art, design, and technical education oriented towards facilitating creativity.

Function-based Modelling and the HyperFun Project in Education

In the Function Representation (FRep) (Pasko et al., 1995), a 3D object is represented by a continuous function of point coordinates through the inequality $F(x,y,z) \geq 0$. Time-varying and other multidimensional objects can be defined by a similar inequality. In an FRep modelling system, an object is represented by a constructive tree data structure (Figure 1 left) reflecting the logic of the object construction, where leaf nodes represent primitives (building blocks) and internal nodes represent operations. The function F is evaluated at a given point by an FRep tree postorder traversal procedure. The noticeable advantages of this representation are its procedural nature and extensibility, or the ability to introduce a new primitive or operation via a small analytical expression or a short function evaluation procedure. The research results on various FRep primitives and operations are reported at the FRep Web page (Shape Modelling and Computer Graphics with Real Functions www.hyperfun.org/F-rep.html). Later (Pasko et al., 2001), a more general constructive hypervolume model was introduced, which supports modelling heterogeneous volumetric objects as point sets with attributes, where an attribute is a mathematical model of an object property of an arbitrary nature such as material, photometric, physical, and others.

There are several projects adapting the FRep modelling paradigm: the general FRep modelling system HyperFun (HyperFun Project, 2012), the skeleton-based implicit surface modelling system BlobTree (Wyvill, Galin, and Guy, 1999), and the function-based extension of VRML and X3D formats called FVRML/FX3D (Liu & Sourin, 2006). In this paper, we present a number of educational case studies based on various FRep software tools including HyperFun. The members of the HyperFun team, a freely associated group of researchers and students from different countries, have contributed to the case studies described in this paper.

HyperFun (Adzhiev et al., 1999; HyperFun Project, 2012) is a programming language supporting all notions of FRep modelling. This language was designed to be a minimalist one in order to allow non-specialist users to create models of complex geometric shapes. A model in HyperFun (see Figure 2) can be constructed using traditional imperative programming statements such as assignment, iteration, and condition. The functional expressions are presented using arithmetic and relational operators, standard mathematical functions as well as special built-in operators, which support fundamental set-theoretic operations (union, intersection, subtraction), and special FRep library functions.

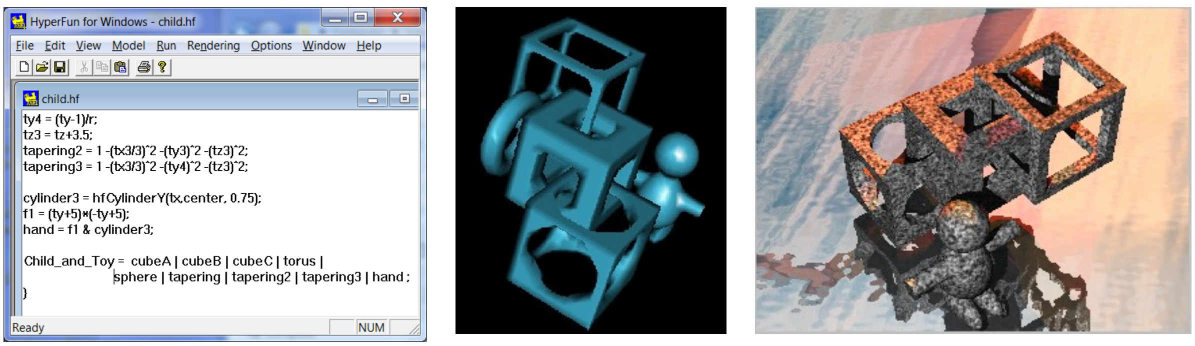


Figure 2: *Example of a HyperFun model fragment (left) and the images of the polygonized (middle) and ray-traced (right) model.*

The FRep library contains the most common primitives and transformations and is easily extensible. There are functions implementing traditional geometric modelling primitives (block, sphere, cylinder, cone, torus) and special implicit surface primitives (blobby objects, soft objects, metaballs). More advanced primitives include convolution objects with various skeletons, pseudo-random solid noise primitives, and objects defined by parametric splines (cubic and Bézier). The typical transformations such as rotation, scaling, translation, twisting, stretching, tapering, blending are supported as well as more advanced operations such as metamorphosis or non-linear deformations driven by control points. Details of the HyperFun language and associated freely available software tools can be found at the HyperFun Project Web site (HyperFun Project, 2012) and in the corresponding publications (Adzhiev et al., 1999; Cartwright, Adzhiev, Pasko, Goto, & Kunii, 2005; Pasko & Adzhiev, 2009).

FRep modelling, HyperFun language, and supporting software tools have been taught at several levels of education starting from elementary schools to the postgraduate university level. The primary target was mathematical education at schools and universities combined with practical experience in modelling, computer graphics, animation, and visualization. More than a thousand school and university students in Japan, Russia, United Kingdom, Norway, France, Slovakia, Austria, Sweden, Albania, and United Arab Emirates studied FRep modelling using HyperFun language in the following courses and exercises: computer graphics, shape modelling, visualization, computer animation, and compiler design. Examples of shape models created by students of different ages and qualifications can be found in the Gallery at the HyperFun Web site (HyperFun Project, 2012).

Teaching FRep and HyperFun in computing classes can go through several stages. As HyperFun is quite a simple language it can be used for teaching the basics of computer programming. At the low level, all the mathematical and geometric modelling concepts can be hidden from students. At a higher level, the underlying mathematical and geometric concepts can be revealed in the courses of linear algebra and analytical geometry, computer graphics, solid modeling, and other specialist disciplines. Finally, at the highest level, the HyperFun language can be used for modelling shapes with complex mathematical and procedural definitions by graduate and postgraduate students in different research areas. Another aspect of using FRep and HyperFun concepts and software is stimulating imagination and facilitating creativity in educating non-computer specialist users such as artists, designers, and students in natural sciences. The case studies presented in this paper are intended to illustrate this branch of our educational practice.

Case Studies in Art, Design, and Technical Education

Augmented Sculpture Project

The Augmented Sculpture project (Adzhiev, Comninos, & Pasko, 2003) illustrates a more complex and creative multilevel activity within our framework. In this project, we introduced and explored an original approach to computer-based sculpting that can be of interest not only for CG professionals but for art students and artists. The purpose was to develop a specific interactive environment with embedded computer-based means of sculptural representation to produce artifacts with a new aesthetics. Viewers experiencing these shapes within a virtual space can also benefit from this technology. One can start from an existing physical sculpture, then create its computer model and manipulate this model to generate new shapes that can eventually be manufactured to produce a new physical sculpture. We call this approach "augmented sculpting" as it extends the existence of physical artifacts to a virtual world and then closes the loop by bringing new computer models into physical existence.

The photographs of the sculptures by Russian artist Igor Seleznev were made available to computer-graphics students of the National Research Nuclear University “MEPhI” via the Web. To create initially sketchy computer models of the sculptures, the students were encouraged to write collaboratively and share the HyperFun code. They then formed groups of two or three to combine their efforts in developing more accurate models. The copies of the physical sculptures were made available to the students at this stage, and the artist himself took part in assessing and discussing the intermediate results with the students. Finally, the students constructed geometric models of the sculptures in the form of programs in HyperFun language using the HyperFun for Windows toolkit, and then generated the final ray-traced renderings using the HyperFun for POVRay toolkit. Figure 3 (top left) shows just one sculpture “Gymnast”, and Figure 3 (top right) shows the ray-traced image of its computer model. Three frames from the animation sequence (implemented by another student who got access to the code of the “Gymnast” model in HyperFun) that brought the “Gymnast” to life are shown in Figure 3 (middle). Note that the sculptures have quite complex shapes with subtle non-regular features, and students could see benefits from using such advanced primitives as convolution surfaces.

Other very interesting sculpting artefacts can be created using a metamorphosis operation. Traditionally, metamorphosis is a complex task that requires the animator to establish a set of correspondence between the initial and final key shapes. In the FRep framework, metamorphosis is performed quite simply by a non-specialist user and can generate intermediate shapes by interpolating between more than two key ones. In the Augmented Sculpture project, students of the Hosei University in Tokyo had received from MEPhI students the Hyperfun code for metamorphosis between three sculpture models (“Gymnast” and two others - “Naked” and “Walking Androgynous”) that made it possible to generate a shape that was actually a weighted sum of all those sculptures. The Japanese students then produced the physical incarnations of that shape using rapid prototyping (RP) machinery and the process called ‘3D printing’. Figure 3 (bottom left) shows three original sculpture models, fabricated using a SLA3500 RP machine. The result of the metamorphosis is shown in Figure 3 (bottom right) fabricated using Laminated Object Manufacturing LOM (KIRA Solid Center).

Figure 3: *Augmented Sculpture Project:*
(top left) real sculpture; (top right) its HyperFun model;
(middle row) frames of the gymnast animation;
(bottom left) models of three sculptures produced by a RP machine;
(bottom right) RP model of the “triangle metamorphosis”.

The next stage of the project was concerned with using an experimental interactive modelling system allowing the artist to interactively navigate through a so-called ‘FRep Sculpture Garden’, which is a time-dependent scene composed of multiple objects. So, the artist experiences an immersion in a virtual space where he or she can generate new shapes using metamorphosis between the sculptures. Editing the shapes on the fly by adding or removing material is also possible. This is a base for an interactive art installation in which physical and virtual artifacts are combined and overlaid (Adzhiev et al., 2003). We believe that projects like Augmented Sculpture are a way of allowing professionals, artists, and students to mix and work together, thus encouraging them to exchange ideas and skills. A more detailed description of the project can be found in Adzhiev et al. (2003).

"Lifetime" Animation

The National Centre for Computer Animation (NCCA) at the Bournemouth University is a leading educational and research school that provides courses at undergraduate and graduate level in computer animation, visual effects, and games (Comninos, McLoughlin, & Anderson, 2010). Its graduates can be found working at major studios worldwide and some Alumni have been awarded Oscars and BAFTAs. On successful completion of “the major project” in the final year, NCCA’s undergraduate students have to produce a body of work (e.g., a computer animation artefact) of professional quality mainly using industrial tools, in particular Maya, which is a major mainstream 3D animation software system. It provides a comprehensive feature set that includes tools for animation, modelling, simulation, rendering, and match moving. Those tools are mainly surface-based and do not provide FRep support, so our group has developed an FRep plug-in to Maya thus extending its functionality. Here we present a final year project by a student Paul Novorol who created an animation called “Lifetime” (Novorol, 2011) using this novel tool.

The main idea for the short animation was to create a human life cycle using animated liquid wax based on a lava lamp. The FRep tool allowed the author to handle a smooth flowing anthropomorphic object whose topology updated and changed frame by frame making it possible to form, blend and metamorph into many different organic and complex shapes within the same sequence. This animation could not be implemented using conventional tools, so the student who intended to work in industry as an artist had to learn some novel modelling concepts and master a research software tool. Figure 4 shows four frames from the animation.

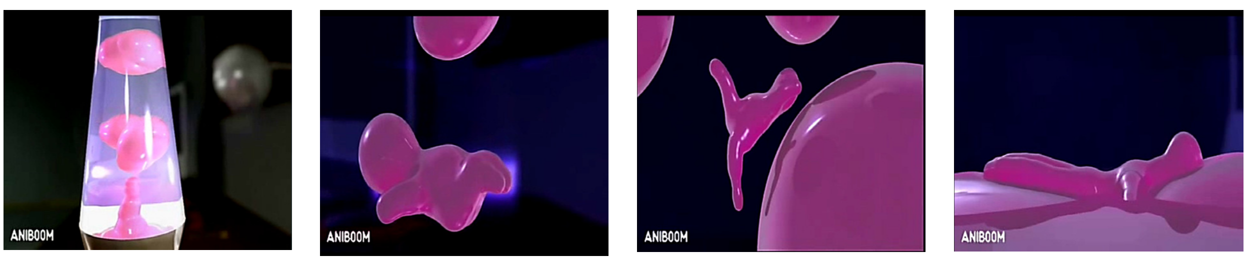
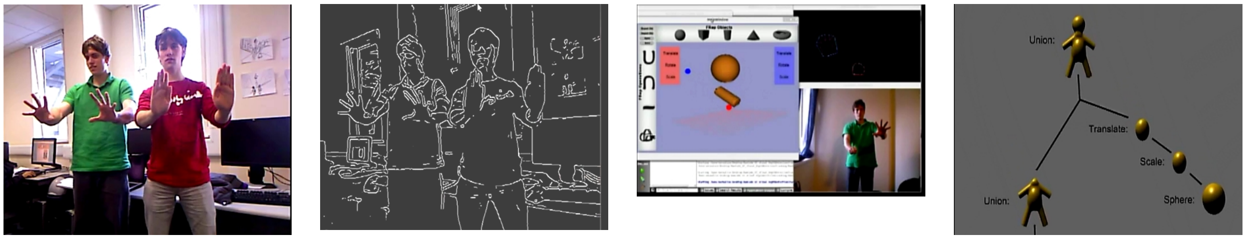


Figure 4: *Frames of the “Lifetime” animation.*

Kinect FRep Modeller

The Kinect FRep Modeller (Glynos, Miltiadou, van Mourik, & Thattarakkal Poothakandy, 2012) was a group project by master’s students at the National Centre for Computer Animation. The goal of the project was software development to allow the users to manipulate objects and to perform constructive modelling with their hands rather than using a mouse and a keyboard. Figure 5 illustrates the main concepts of the project. The core of the project technology is built around the Kinect sensor device (Glynos et al., 2012) providing the depth data together with the video signal. This allows for tracking body motion including hand gestures (Figure 5a). In the project, the hand detection is implemented through contours (Figure 5b). The detected hands are represented on the screen for feedback by the blue and red cursors (Figure 5c). A basic hand grab gesture has been implemented to perform such actions as selecting a primitive or operation from the menus, rotating the camera and moving the objects in the scene. A FRep library supporting the constructive modelling (Figure 5d) has been implemented and includes basic geometric primitives and set operations. The current object is rendered using its surface polygonization. Several test models have been produced and the modelling process documented in a video (Glynos et al., 2012). The main intent of this technical project is to provide means for users to express their creativity by using their hand gestures to construct 3D shapes in a game-like environment.

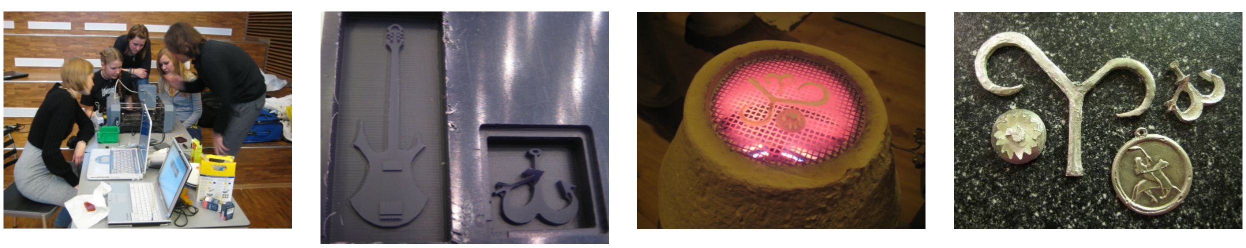


a b c d

Figure 5: *Kinect FRep Modeller concepts: a) user control with hand gestures; b) hands detection using a Kinect camera; c) a cursor attached to either hand; d) constructive modelling using the menus of primitives and operations.*

Jewelry Design and Fabrication

In the design school Breivang in Tromsø, northern Norway, students learned how to take their designs from a paper sketch, to a 3D digital model, and then to fabricate a customised piece of silver jewelry (Figure 6). The students were taken through the entire process, starting with the design concept on paper. After a few sessions in 3D software and HyperFun in particular, they transferred their designs from paper to digital 3D models. A wax cast was made for each student’s 3D model using a Roland Modela MDX-20 desktop milling machine. Next the students used the special Art Clay material consisting of silver particles and organic binder to fill their casts, which were then dried, fired on a portable kiln, further polished and stylized by the students using traditional jeweller's tools. More details on the technological process can be found at Vilbrandt, Vilbrandt, Pasko, Stamm, and Pasko (2011). Each of the students who participated in the class ended up with a digital model and a real piece of silver jewellery from their original paper design.



a b c d

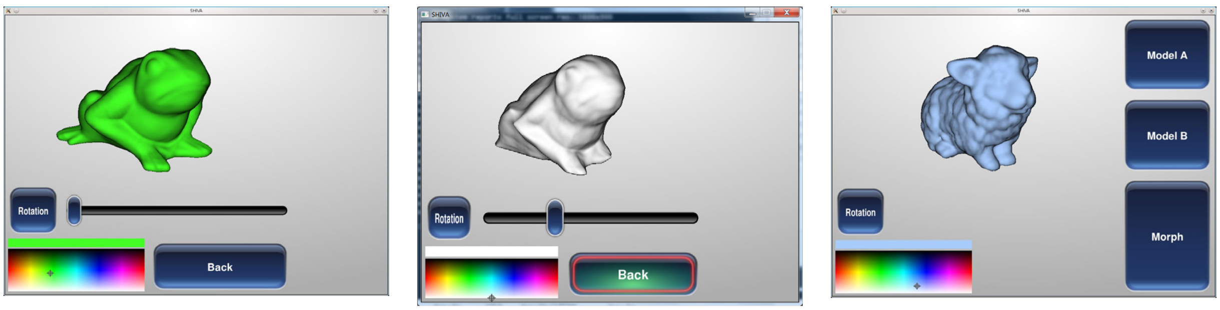
Figure 6: *The process of silver jewelry fabrication: a) wax cast producing with Modela milling machine; b) samples of wax casts; c) silver clay objects fired on a portable kiln; d) final silver artefacts.*

SHIVA Metamorphosis Exercise

The EU sponsored SHIVA Project (Sculpture for Health-care: Interaction and Virtual Art in 3D) brings together several computer science, educational, and medical partners from the UK and France. The main idea behind SHIVA is to give people with disabilities an opportunity to do something in the area of 3D modelling as a way of enhancing their creativity and expressing themselves. The project team develops computer-aided exercises to support a range of different patient activities.

One of the developed exercises allows for children with disabilities to perform a metamorphosis transformation between two arbitrarily selected 3D shapes (Figure 7) (Mcloughlin et al., 2012).

The main design issue for this exercise was the simplicity and adaptivity of the graphical user interface, which is aimed to support the students with very limited motor skills including those operating with a single switch (large push button, lever switch, eye-blink trigger). Typical computer-aided activities used by disabled children include typing text and performing other simple tasks on the 2D surface of the computer screen. Providing them with the ability to operate with 3D shapes is thought to stimulate their imagination and to bring satisfaction from using the computer. There are several other exercises under development such as axis-aligned and free-form constructive modeling. The project aims to be completed with an exhibition, which will display the sculptures of the disabled students. This will be made possible through the use of desktop 3D printers.



a b c

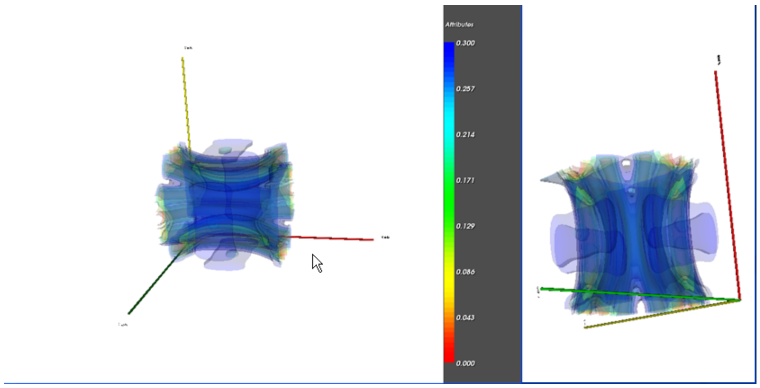
Figure 7: *Screeenshots of the 3D metamorphosis exercise of the SHIVA project: gallery shapes (a and c) and an intermediate shape (b).*

Scientific Visualization in Physics Education

Nowadays it is especially important for students in physics to have skills in computer modelling physical objects and processes that can be very helpful in their research work. As scientific visualization tools are widely used for analysis of computer modelling results, students in physics are often taught to visualize results of computer modelling as well. We describe here the experience of using HyperFun as a scientific visualization tool for analysis of various physical objects and processes that are the results of computer modelling work done by physics departments at the National Research Nuclear University "MEPhI" (Moscow, Russia). Most frequently, the studied results of computer modelling are physical scalar fields. Students are taught to consider different static and dynamic spatial images of computer modeled scalar fields in the process of their analysis by means of scientific visualization.

The studied scalar fields were given as functions of several variables defined on domains represented as geometric objects that also could be defined by functions of several variables. A functional description of a scalar field and its domain was obtained as the result of computer modelling within students' research work. Such description of the studied physical object was presented in a file in the form of numerical data that should be analyzed. The example of scalar field visualization is shown in Figure 8. To obtain these results several additional file reading based primitives and attribute functions were added to the HyperFun FRep library and used with the resulting HyperFun model. The visualization presented in Figure 8 was made through the Visualization Toolkit (VTK) based interface for HyperFun. These graphical representations of spatial scenes corresponding to the second type superconductor computer modeled with Ginzburg-Landau equations help students to form statements about the physical variable under study, namely the scalar order-parameter field distribution in the selected space area.

One more example is “The Principles of Scientific Visualization” course, which is taught to graduate students in physics at the National Research Nuclear University "MEPhI". This course was developed by the “Scientific Visualization” laboratory with the close support of physics departments and the National Centre for Computer Animation, Bournemouth University, UK. The purpose of this course is studying the theoretical principles of scientific visualization and acquisition of practical skills in development of application software in scientific visualization. In general, the course aims to develop the students’ spatial creative thinking while solving problems of scientific data analysis. So, this course teaches students to consider and manipulate the corresponding spatial images, make their visual analysis and interpret the analysis results in terms of the application area.



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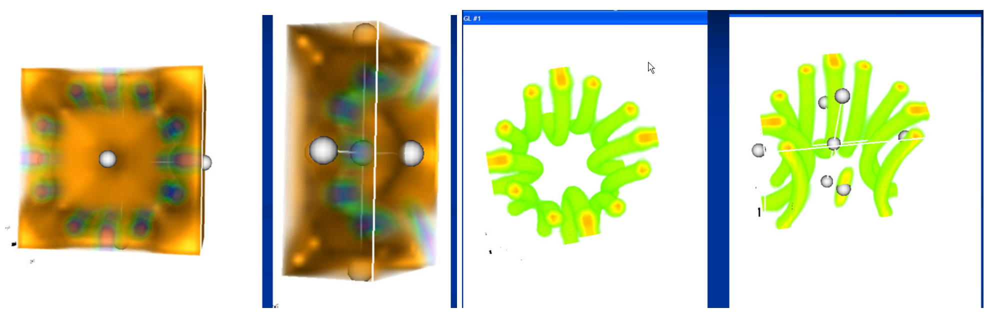

b c

Figure 8: *Scientific visualization example for the order-parameter field for the second type superconductor (Abrikosov vortices). Different approaches to scalar field visualization: a) isosurfaces; b) volume visualization with the scalar field defined on a rectangular domain; c) scalar field on a complex domain defined by one of the field's isosurfaces. The field’s domain can be interactively cross-sectioned by the user with planes controlled by white handles.*

The course includes the following three sections: scientific visualization concepts and capabilities, scientific visualization tools, and scientific visualization applications. The second section includes an introduction to HyperFun as well as other software tools that can be used for solving problems of data analysis by scientific visualization means. Students may write application scientific visualization software on the base of HyperFun in the practical part of the course. To support this, the HyperFun language was extended: the program functions of file opening, closing, reading, writing were added to the HyperFun API. An example of an application software on the base of these functions is given in the second section of the course. It should be mentioned that HyperFun was also used for the course multimedia training materials design that students have an opportunity to use.

Conclusions

Constructive function-based geometric modelling can be seen as a highly specialized subject interesting only for professionals. Our experience shows that it can be mastered and appreciated by students at different levels of education as an activity stimulating and supporting their creative thinking.

In the social context of the presented educational technology, we emphasize the active, creative, and collaborative character of the learning process presented in this paper. Indeed, the building of object models starts from rather abstract mathematical expressions, utilizes ready made building blocks in the form of library functions, then goes through interactive modelling in the virtual world, and finally results in the fabrication of physical artefacts. In this process, the learner obtains tangible instances of their creative designs. This can be considered a practical confirmation of the idea of the constructionism theory that learning is most effective when the learner creates a meaningful product actively using their imagination supported by advanced computer technology.

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Biographies

Alexander Pasko is a professor at The National Centre for Computer Animation, Bournemouth University, UK. He received his PhD from Moscow Engineering Physics Institute (MEPI) in Russia in 1988. His main research interest is development of a high-level universal model for spatial objects and phenomena with their internal properties. To support the mathematical concepts of this model, Alexander and his colleagues introduced and develop the special-purpose modeling language called HyperFun (from Hyper-dimensional Functions), which has extensive applications in education, computer animation, biology, digital fabrication, and other areas. Alexander has published more than 120 papers in academic journals and conferences.

Dr Valery Adzhiev is a senior research lecturer at The National Centre for Computer Animation, Bournemouth University, UK. He received his PhD in Computer Science from Moscow Engineering Physics Institute (MEPhI) in Russia in 1992. The main focus of his research is on Functionally-based Geometric Modeling and its applications in Computer Animation, Computer Art and 3D Fabrication. He also specializes in programming languages and compilers, especially for geometric modeling and animation applications. He is a designer of HyperFun modeling language. Valery has published more than 70 refereed papers in academic journals, conference proceedings and books.

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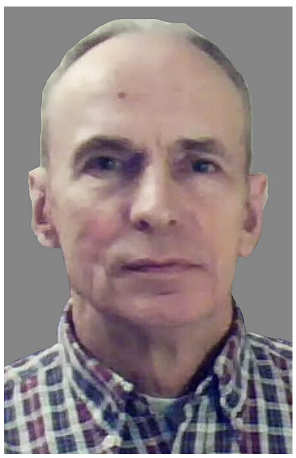

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Using Adult Learning Principles as a Framework for Learning ICT Skills Needed for Research Projects

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Executive Summary

Students in higher institutions need to carry out research projects. The focus of this paper explores a model to help students learn ICT skills needed for research projects. Generally students go through the 'long and hard route' to learn and use ICT resources because they do not know how to do it. The paper explores the Adult Learning Theories as a model to develop the contents of an ICT information resource. Adult learning requires building on prior learning, using methods that treat learners with respect, and recognizing that people have different learning styles and have a variety of responsibilities and time commitments. The optimal role of the adult learner in the learning situation is that of a self-directed, self-motivated manager of personal learning who collaborates as an active participant in the learning process and who takes responsibility for learning. The modules developed were for Computer Operations, Internet, Microsoft Word®, Microsoft Excel® and PowerPoint®. Forty-four students who volunteered evaluated the information resource. Based on the evaluation and comments and question from the students, the design of the information resource can be adjudged highly successful. All the functional requirements were met in the ICT information resource design. Students from three (3) out of the four (4) faculties rated their satisfaction of the functionality of the system at 100%. The students highly regarded the perceived usefulness of the ICT information resource. Eight out of the 9 items related to perceived potential usefulness were rated at over 90%, while only one item was rated at 88.6%. Over 90% of the students agreed that the system has been designed with an understanding of their ICT skills need. In 9 out of the 10 items related to task technology fit, 85% of the students agreed to the Task Technology Fit. It is therefore expected that with the high level of their satisfaction with the perceived potential usefulness, and Task Technology Fit, the ICT information resource will be accepted, adopted and used by the students.

Keywords: Adult Learning, Self-Directed Learning, ICT Skills, Research Projects, Information Resource

Introduction

Currently, many colleges and universities all over the world require students to demonstrate a prescribed level of computer proficiency. Many educational institutions offer introductory computer courses to assist students in meeting this requirement. The assumption is that these skills taught at the beginning of stu-

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dents' career will be able to carry them through the course or university life. However, research shows that this may be more of a perception than reality.

A study was carried out to analyze, design, and develop a prototype ICT skills information resource for final year undergraduate students to enable them to acquire ICT skills for their research work. There were several aspects to this study and they were based on different models. The focus of this paper is the instructional design aspect as well as the presentation of the results of the students' evaluation of the model used in the study. The modules developed were for Computer Operations, Internet, Microsoft Word®, Microsoft Excel® and PowerPoint®. A detailed description of the information resource can be found in Eyitayo (2012).

Most theories of adult education place great value on prior learning and experience of adults, as well as relevance to the learner. Adult learning requires building on this prior learning, using methods that treat learners with respect, and recognizing that people have different learning styles and have a variety of responsibilities and time commitments. The optimal role of the adult learner in the learning situation is that of a self-directed, self-motivated manager of personal learning who collaborates as an active participant in the learning process and who takes responsibility for learning (Collins, 2004; Nesbit, Leach, & Foley, 2004). Although this study is not about the adult learner, quite a number of the principles related to the adult learner are applicable to learning online. A major reason is that the online learner is mostly a self-directed learner. This is the principle behind the prototype design in this research.

This paper therefore discusses the methodology for the design, focusing on the use of adult learning principles and evaluating the developed resource. The three major research questions for the student evaluation review were:

1. What are the functional requirements for the ICT skills information resource?
2. What are the students' perceptions of the task-technology fit of the prototype system? and
3. What are the students' perceptions of the potential usefulness of the prototype system?

Background to the Study

The term 'Research Project' in this study refers to the undergraduate research done in the final year of study in the university. A typical research project requires word processing of a long document, some form of analysis, and a presentation. It sometimes also requires drawing charts, inserting pictures, copying data and graphics across applications, good internet skills, and managing citations. Though research itself is already a huge task to perform, students need adequate ICT skills to enable them handle all the activities linked to the research project.

ICT skills are a fundamental requirement for students and workers in the digital age. In schools, universities and in the work place, the question of how to utilize ICTs for learning purposes has become more and more important for anybody engaging in education and training as new technologies are spreading rapidly (Welle-Strand & Thune, 2003, p. 1). Even if a learner is not doing what directly relates to computing, ICT skills are required to do most assignments and projects. In fact, virtually all university courses require basic computer knowledge. Similarly, more and more jobs are demanding that workers become increasingly familiar with using a wide range of computer applications.

In almost all departments at the University of Botswana, the independent research project is a common form of assessment required of final year students at undergraduate level. They are required to use their knowledge and skills to design experiments, analyze data, generate results, and ultimately present their research efforts and results in the form of a final research project report. The ICT skills required are normally expected to be acquired by students partly through two General Education Courses taught in Year 1 to new students across two semesters. Each of the courses carries a weight of two credits. The University of Botswana (UB) uses the General Education Module approach to increase students' general education experience. However, looking at the requirements for ICT competencies, it is evident that this model will not meet the ICT competency requirements for a research project, thesis or dissertation. This is because the course is taught at first year and the skills taught do not cover the whole experience required in the university. Also when students are taught in the first year, they are likely to forget the skills before their final year (Eyitayo, 2011).

This researcher has been involved for several years in supporting final year undergraduate and graduate research students at UB and has noticed, in particular, a lack of basic ICT knowledge as students struggle with most computer applications. Most of the students spend a lot of time on simple ICT tasks, which indicates lack of adequate ICT skills. This lack of skills makes students to spend a lot of valuable time learning ICT skills simultaneously with doing their research projects. Sometimes, due to lack of skills, students use some of the ICT tools in most inefficient ways. A student for example can type the table of contents for a document separately and keep changing the pagination in the table each time corrections are made. This is a clear waste of time and a more efficient use of the application requires that this should be done with the use of the table of content feature in the application. Another common example is how to paginate a document based on different sections, which most students do not have the expertise to do. There have also been cases of students who have lost their entire project documents by accidentally saving blank documents over previously edited and saved versions of their documents. This is a clear case of not knowing how to make backups of their work. The examples above may be an indication that they do not have the necessary information to do things correctly. It is against this background that the researcher became concerned with the special ICT challenges facing undergraduate students and the need for a resource where they can find information to help them acquire the fundamental ICT skills required for their final year projects (Eyitayo, 2011).

Students and ICT Skills: A Review of Literature

Some institutions assume that students have acquired both computer knowledge (concepts) and computer skills before entering the University. Some are considering eliminating introductory computer courses with the expectation that students will demonstrate adequate computer knowledge through the proficiency examination (applications) in high school or through other personal experiences (Wallace & Clariana, 2005, p. 1). However, research shows that the assumption that the students are skilled may be more of a perception than reality. This is confirmed in a statement by McEuen (2001, p. 16), "To say that our students, having grown up with digital media in their homes and in their schools, come to SU already equipped with skills and knowledge of information technology is a misconception." In a study carried out by McDonald (2004) on the computer literacy of students majoring in computer information systems (CIS) at Georgia State University in the USA, the results of the two-month pilot showed that 28.4% of graduate students failed to pass all six exams. For undergraduate students, the results were much worse with over 50% of CIS undergraduate majors not being successful.

A similar study of 140 incoming business freshmen in the School of Business at the College of New Jersey was carried out by Wallace and Clariana in 2005 to determine if students had adequate computer knowledge and skills to exempt them from an introductory computer fundamentals course. The results showed that the assumption that incoming freshman business students possess adequate knowledge of both computer concepts and computer literacy skills may not be accurate. The average scores of 58% on the concepts pre-test and 60% on the Microsoft Excel® pre-test respectively suggest that students do not possess the necessary skills to function in an undergraduate School of Business. In the study, 64% of the students failed or scored below 60%

in one of the two tests indicating that only about one third of the freshman business students tested could be exempted from the course. They also noted that while some students may eventually pick up some computer skills during the course of their degree programme, they would most likely learn them imperfectly and not to the degree that is required.

Another study was carried out in 2007 at the Northern Arizona University because there was a debate on the appropriateness of the introduction to computer information systems course with the "increased" computer proficiency of incoming freshmen. A pre- post-test was conducted to provide information on the level of the computer conceptual knowledge for the college of business students. The results of the study showed that most students did not possess sufficient proficiency to be exempted from the course. Nineteen of the original 80 students (a little under 24%) achieved a score equal to or greater than 60% in the pre-test. Even those students who achieved a passing score (60%) after going through the course increased their computer conceptual knowledge by only 15% (VanLengen, 2009).

A more recent study by Karsten and Schmidt (2008) analyzed computer self-efficacy for two independent samples of students enrolled in an introduction to information systems course in 1996 and 2006 at the University of Northern Iowa and compared the results of the two years. They discovered that significant and substantial increases in computer experience and use did not translate into significantly higher levels of Computer Self- Efficacy (CSE) for the 2006 students. Their explanations for the results were that they suspect that students use computers much more frequently to communicate with others than to perform the kinds of information processing and problem-solving tasks required in introductory information systems courses. Social networking, e-mailing, text messaging, and instant messaging result in extensive computer use that requires the repetitive use of a limited range of skills, primarily entering text. Another possible reason they gave was that though students indicate that the number of courses that require computer use has significantly increased, the computer skills required in some of the courses may be narrow (e.g. word processing, presentations) or not consistently required, reinforced, or integrated across courses. Finally, they proposed that educators may sometimes fail to help make the connection between the skills and experiences students have and they may not actually realise the students have the skills expected. A similar study by Bond (2010) comparing undergraduate nurses' ability in 2004 and 2007 revealed increased basic skills, however, the ability to carry out more complex tasks did not improve over the years. Langley (2012) stated that although students may be labeled "digital natives", these students may not know how to employ technology-based tools strategically to optimize learning experiences in university settings.

Apart from freshmen, a few studies have been carried out on senior students in university environment. EDUCASE Center for Applied Research (ECAR) conducted a study of undergraduate students and their information technology skills in 2007 (Caruso & Salaway, 2007). The survey used a questionnaire with a five-point scale rating of 1 (poor), 2 (fair), 3 (good), 4 (very good) and 5 (excellent) to ask students about their perception of their technology skills. The respondents who were seniors rated themselves as more highly skilled than those who were freshmen in online library skills, with 54.3% reporting "very good" or "excellent" skills compared to 40.3% of freshmen respondents. Respondents reported a similar pattern for spreadsheet skills. For other skills surveyed, which were course management system, presentation software, and computer maintenance, there was no meaningful skill difference between seniors and freshmen.

Another study by Kaminski, Switzer, and Gloeckner (2009) of university students' fluency with information technology measured students' proficiency on a four point scale of 1(very proficient) to 4(never used). The results revealed that seniors were between "very proficient" and "somewhat proficient" in word processing (1.30), browser (1.32), and presentation software (1.81). They reported feeling "somewhat" and "marginally proficient" in graphics (2.70), while desktop publishing (3.15) and databases (3.15) were both reported close to "marginally proficient", web animation (3.36), web development (3.37), programming (3.63), digital video (3.69), and digital audio (3.75) were all between "marginally proficient" and "never used". There was no significant difference in perceived ability for word processing, spreadsheet, graphics (Adobe, Photoshop, and Illustrator) and web development (Dreamweaver). All of the above studies were carried out in the developed world.

A study of the information and communication technology use by the world's children and youth carried out in 2008 by the International Telecommunications Union revealed that the level of ICT use is higher in the more developed economies. The reasons for this include better (and cheaper) access to ICT infrastructure and higher levels of discretionary spending per capita. If the gap between the developed and developing world is anything to reckon with, one might not expect a higher level of competency in universities in the less developed countries.

The lack of skills shown from the survey of Business and Computer Information Systems students in the various institutions of higher learning above could be an indication that some university students do not have the necessary skills for all the stages of their university existence. Usually Science and Business faculties are generally among the best skilled in ICT literacy than other faculties. This can also be confirmed by the results of University of Botswana (UB) students in the Computing and Information Skills Fundamentals courses over three years, students from these two faculties (Science and Business) always have had the best results (Department of Computer Science, 2010).

Adult Learning Theory

Instructional design is concerned with the promotion of processes that lead to successful learning regardless of the delivery medium being used, and it needs to be based upon appropriate learning theories (Smith & Ragan, 1999). In this case principles from adult learning were found to be the most relevant for the design.

In the andragogy theory developed by Knowles (1980), four key principles of adult learning are identified. The principles are that (i) adults need to be involved in the planning and evaluation of their instruction; (ii) experiences (including mistakes) which adult learners bring to the training environment provide the basis for learning activities; (iii) adults are most interested in learning subjects that have immediate relevance to their job or personal life; and (iv) adult learning is problem-centred rather than content-oriented (DiLello & Vaast, 2003).

The implications of this theory for design of the information resource are that the:

- tasks to be included are those identified and confirmed by final year students and their departments as required skills. This is based on the principle that adults need to be involved in the planning and evaluation of their instruction.
- design will concentrate on tasks students need to perform in their final year project. This is based on the principle that adult learning is problem-centered rather than content-oriented.
- content of instruction will concentrate mainly on final year project tasks, so that final year students can find the information they need easily. This is based on the principle that adults are most interested in learning subjects that have immediate relevance to their job or personal life
- students are told direct steps on how to perform a specific task at a time, without the normal long process of computer instructions. Students' previous experience will be tapped into, since they already know how to use computers and just need specific information on how to perform specific tasks. Instructions will therefore be broken into

chunks where students can find answers to questions on “how do I perform a particular task in an application”? This is based on the principle that students’ previous experiences provide a basis for learning. Also the role of the student in the learning situation is that of a self-directed, self-motivated manager of personal learning who takes responsibility for learning.

Methodology/Design

Based on the input from the analysis stage of the research, the subject contents of the information resource were finalized. The advanced skills that make research projects easy were identified. The information resource was designed based on identified competencies of students across the various departments. The subtopics and levels were also identified. The aim of the resource was not training but to give appropriate answers to specific questions that a student might have while working on their project. In the design, lessons learned from adult and self-directed learning as highlighted in the literature review were taken into consideration. The components taken into consideration were relevance/involvement, previous experiences and control over learning. This is illustrated in Table 1.

Table 1: Components of self-directed and adult learning

Component	Description
Relevance/ involvement	Tasks included were those identified and confirmed through the survey by final year students and their departments as the required skills. The design concentrated on ICT tasks students need to carry out their final year project.
Previous experiences	Students were directed on the steps required to perform specific tasks without the normal long process of computer instructions. The instructions were broken into chunks of how to perform specific tasks.
Control over learning	The components were divided into computer operations, e-mail, Internet, Microsoft Word®, Microsoft Excel® and Microsoft PowerPoint®. Under each subtopic, the major questions were identified and the appropriate answers provided.

The creation of an effective online environment requires thoughtful and appropriate design of the content materials (Siragusa & Dixon, 2005). Eckersley (2003) observes that ICT literacy is most effectively developed through relevant and contextual use of ICT technologies. Concentrating on skills required in the final year projects puts the design in this context. Lee, Pliskin, and Kahn (1994) also state that computer literacy skills should be developed in a way that motivates and empowers students to use skills in the most effective manner possible so that students’ prior experiences can be effectively acknowledged and built upon.

The prototype ICT information resource was designed based on identified competencies across the various departments. The aim of the resource is to give appropriate answers to specific questions students might have while working on their undergraduate research projects and expose them to the more advanced skills that make research work easier. The information needs analysis carried out helped to determine what the ICT information resource should contain. Confidence in accessing online courses was used to determine if eLearning would be a good medium to deliver the content. The results showed that students had a high level of confidence in accessing online courses, which confirms that it will be a good medium for the Information Resource. Email skills of the students were generally good and are not required for the research report and so it was excluded in the modules. With SPSS®, training would be required because the students’ skills were quite low to benefit from an information resource. Also, the results show that SPSS® is not a package required generally across all faculties, which is one of the conditions to include any component in the Information Resource. In total, there were five modules included in the Information Resource namely: computer operations; Internet; Microsoft Word®; Microsoft Excel® and Microsoft PowerPoint®.

The Information Resource would allow students to check and find what they want and easily print or download what they find, with little or no distractions and minimal graphics. The structure of the information resource is a standard hierarchical arrangement with a capacity for non-sequential navigation following the Lynch and Horton (2002) hierarchical model and the digital content framework. In the design, lessons learned from adult and self-directed learning were taken into consideration.

During the data collection of the information needs analysis, students were asked to indicate if they would like some assistance with some ICT skills that will help with their research project. A total of eighty four (84) responded in the affirmative. E-mails were sent out, though some were returned due to wrong addresses. A total of forty-four (44) students evaluated the system in six (6) sessions. Each section included an introduction and demonstration before the students were asked to interact with the system. At the end there was an interactive session where students discussed freely before they were asked to fill the evaluation questionnaire. Each session lasted about two (2) hours. The evaluation sessions took place between the end of April and early May in 2010.

The evaluation questionnaire comprised of four (4) sections. The first section was on demographic information of the respondents. The second section had nine (9) items that were based on the perceived potential usefulness and were adapted from Davis (1989) instruments. The third section had ten (10) items that were related to the task technology fit using a construct from Thompson, Higgins, and Howell's (1991) factors influencing the utilisation of Personal Computers (PCs). Task-technology fit used a construct task-technology fit measure from Thompson et al.'s (1991) factors influencing the utilisation of Personal Computers (PCs). The factors they used were based on the extent to which users agree with statements relating to potential application of PCs for related job efficiency, effectiveness, quality, and overall performance improvement, and measures, using 39 items on a 5 point likert scales ranging from strongly agree to strongly disagree. Of the 39 items, 19 were adapted for the evaluation. Ten items were related to the task technology fit while nine were based on the perceived potential usefulness and were adapted from Davis (1989) instruments. An additional question about the overall comments on the prototype was included at the last section of the questionnaire.

Data analysis involved the applications of standard statistical validity and reliability metrics. The research instrument validation was conducted using factor analysis and Cronbach alpha because some of the survey items and key constructs of the study have never been tested and used before. The collected data was analysed using percentage frequency analysis.

In summary, the relationship between the development methodology/instruments and the research questions are shown in Table 2.

Table 2: Relationship between instruments and research questions for design aspect

Research Question	Evaluation Model	Study Sample
What are the functional requirements for the ICT skills information resource?	Thematic analysis of students' use and evaluation	44 undergraduate students from various departments
What are the students' perceptions of the task-technology fit of the prototype system?	Task-Technology Fit	44 undergraduate students from various departments
What are the students' perceptions of the potential usefulness of the prototype system?	Perceived Potential Usefulness	44 undergraduate students from various departments

The evaluation scale was measured using 19 items. Reliability testing of these items using Cronbach Alpha indicated a strong reliability coefficient of α=.836. Most of the items had high item to total correlation. There was no significant increase in reliability from dropping any of the scale items, and none of the items was dropped.

Findings and Results

The respondents for this survey were students in their final year in six faculties in the University of Botswana. The sample consists of sufficient numbers to meet the requirements for statistical significance as determined by statistical methods. The forty-four (44) students were from four (4) faculties: 8 (18.2%) from Business, 17 (38.6%) from Humanities, 4 (9.1%) from Science, while 15 (34.1%) were from Social Sciences. The distributions of the students who evaluated the system revealed that 17 (38.6%), of them were female while 25 (56.8%) were male. Of the 44 students, 2 (4.5%) were below 20 years, 30 (68.2%) were between 20 and 25, 9 (20.5%) were between 25 and 30 years, while 3 (4.6%) were above 30 years.

It can be seen from Table 3 that students highly regarded the perceived usefulness of the ICT information resource. Over 88% of the students' responded with either strongly agree (5) or agree (4) in all the 9 items related to the perceived usefulness.

Table 3: Percentage summary of perceived potential usefulness

	1 Strongly Disagree	2	3	Sum (1-3)	4	5 Strongly Agree	Sum (4-5)
Using the system will give me greater control over the ICT skills I need for my research project	0	2.3	0	2.3	27.3	70.5	97.8
Use of the system will significantly increase the quality of my report	0	0	2.3	2.3	20.5	77.3	97.8
Use of the system will increase the effectiveness of ICT tasks for my research project	0	0	0	0	43.2	54.5	97.7

	1 Strongly Disagree	2	3	Sum (1-3)	4	5 Strongly Agree	Sum (4-5)
Using the system will make it easier for me to write my report	2.3	0	0	2.3	34.1	63.6	97.7
I will find the system useful in my work	0	2.3	2.3	4.6	22.7	72.7	95.4
Use of the system will increase the quality of my research for the same amount of effort	0	0	6.8	6.8	34.1	59.1	93.2
The system will enable me to complete my research project more quickly	0	2.3	6.8	9.1	29.5	61.4	90.9
Using the system will allow me to accomplish more work than would otherwise be possible	0	2.3	4.5	6.8	31.8	59.1	90.9
The system will support critical aspects of my research project task	2.3	2.3	6.8	11.4	38.6	50	88.6

However, when grouped into faculties, the perceived usefulness was rated at 100% by all except for Humanities where it ranged between 70 and 94%, as shown in Table 4. The result supports the findings at the analysis stage that showed that Humanities students seem to have better ICT skills for research than other faculties.

Table 4: Percentage summary of perceived potential usefulness by faculty

	Agree/Strongly Agree			
	Business	**Human-ities**	**Science**	**Social Sciences**
Using the system will give me greater control over the ICT skills I need for my research project	100.0%	94.1%	100.0%	100.0%
The system will enable me to complete my re-search project more quickly	100.0%	78.5%	100.0%	100.0%
The system will support critical aspects of my research project task	100.0%	70.6%	100.0%	100.0%
Use of the system will increase the effectiveness of ICT tasks for my research project	100.0%	100.0%	100.0%	100.0%
Using the system will allow me to accomplish more work than would otherwise be possible	100.0%	82.4%	100.0%	100.0%
Using the system will make it easier for me to write my report	100.0%	94.1%	100.0%	100.0%
Use of the system will significantly increase the quality of my report	100.0%	94.1%	100.0%	100.0%
Use of the system will increase the quality of my research for the same amount of effort	100.0%	88.3%	100.0%	100.0%
I will find the system useful in my work	100.0%	88.2%	100.0%	100.0%

As shown in Table 5, over 86% of the students responded with either "agree" or "strongly agree" in 9 out of the 10 items related to task technology fit. The only exception is on the item 'The system is not missing critical information that will be useful in the task of my research project', for which 77.3% "agreed" or "strongly agreed" that it met their needs. Overall, students felt that the ICT information resource fitted into their task and they can easily follow the steps.

Table 5: Percentage summary of evaluation of Task Technology Fit

	Strongly Disagree	**2**	**3**	**Sum(1-3)**	**4**	**Strongly Agree**	**Sum (4-5)**
The section headings clearly indicate what information is contained within the section	0	0	2.3	2.3	40.9	56.8	97.7
It is easy to determine what information is available in the resource	0	0	6.8	6.8	43.2	50	93.2
Data from different sources are combined appropriately in the information resource	0	0	6.8	6.8	40.9	52.3	93.2
I can count on the system to be consistent	0	0	6.8	6.8	40.9	50	90.9
The system has been designed with an understanding of my ICT skills need	0	0	6.8	6.8	34.1	56.8	90.9
I am satisfied with the functionality of the system	0	0	6.8	6.8	31.8	59.1	90.9
The system delivers solution to support my research project ICT tasks.	0	0	6.8	6.8	34.1	56.8	90.9
The steps to follow in any task are clear	0	0	9.1	9.1	52.3	36.6	88.9
It is easy for me to understand what each question in the information resource is intended for	0	0	11.4	11.4	50	36.4	86.4
The system is not missing critical information that will be useful in the task of my research project	2.3	0	20.5	22.8	40.9	36.4	77.3

When this was grouped into faculties (see Table 6), the task technology fit was more suited towards Science students, closely followed by Social sciences and then Humanities. Business students rated some items in the task-technology-fit quite low. From the qualitative response to some of the questions on the questionnaires, more business students require the use of SPSS® and other specific applications such as ACCPAC for their research, and this might be reason for their rating.

Table 6: Percentage summary of evaluation of Task Technology Fit by Faculty

	Agree/Strongly Agree			
	Business	**Humanities**	**Science**	**Social Sciences**
It is easy for me to understand what each question in the information resource is intended for	62.5%	100.0%	100.0%	86.6%
The steps to follow in any task are clear	87.5%	88.8%	100.0%	100.0%
I can count on the system to be consistent	87.5%	82.4%	100.0%	100.0%
The system has been designed with an understanding of my ICT skills need	100.0%	76.5%	100.0%	100.0%
I am satisfied with the functionality of the system	100.0%	82.3%	100.0%	93.4%
The system delivers solution to support my research project ICT tasks.	100.0%	82.4%	100.0%	93.4%
It is easy to determine what information is available in the resource	87.5%	94.1%	100.0%	93.4%
The system is not missing critical information that will be useful in the task of my research project	62.5%	76.5%	75.0%	86.6%
The section headings clearly indicate what information is contained within the section	100.0%	100.0%	100.0%	93.4%
Data from different sources are combined appropriately in the information resource	87.5%	94.1%	100.0%	93.4%

The students' narrative comments supported ease of use and usefulness of the resource. Other comments suggested adding it as part of the curriculum and introducing students to it earlier. There was also a suggestion on including SPSS® in the resource. Details of the students' comments are reported below. The R and the number is just an assigned number to the respondent.

Comments from Students from Faculty of Business:

R4: "This session has been very helpful; however, I feel that access to our Moodle accounts should be extended beyond a semester. If this is not possible then perhaps a small booklet could be useful."

R8: "This is an excellent online module and it has been extremely helpful to me. I wish it had come earlier than in my final year semester. It is simple and easy to understand. I wish however that there were resources about SPSS® as that would have been even more useful."

R12: "The system is very good."

R 39: "The Information Resource is quite good since it's something we would be using anywhere we find ourselves so the demo should be done at least twice a semester in order to be of good help to the people who are writing projects and stuffs."

R41: "The information I got from the short demo was useful and it shed light on some things I did not know was possible. I think the ICT skills should be provided to all the 3rd year who will be doing a research project."

R42: "It is easy to understand and very useful for research projects and reports. It saves time and helps in avoiding mistakes."

Comments from Students from Faculty of Humanities:

R9: "The information resource is useful as it gives a quick guide on what to do."

R10: "I wish the system was introduced before I started the research. It has critical information for the research project."

R13: "It should be provided to students in their first year to UB so that they know this information when doing their assignment."

R15: "The lessons made it easier to learn the skills and use when appropriate. It is very important to give completing students a semester lesson on ICT skills."

R16: "I recommend that this lesson should be provided to students every year so that we get to know almost everything about ICT skills. It is very good and I am so happy to be part of it."

R17: "The system is very good and of course very convenient. This is something we could have been taught at first year level as a course and not now!"

R18: "The ICT skills that I've learnt are very useful and it would be important if all students could get access to this system as it would make their work a lot easier."

R19: "The system is very good, quick and convenient. It just came at the wrong time. Next time it will be important if it is done at first year level."

R20: "This type of knowledge would be useful to all students in the university; I therefore suggest that the ICT skills be taught at first year level."

R23: "It was excellent. I wish it was taught at first year because it is omitted in our General Education courses."

R28: "This lesson showed more easier ways of doing things. I have been doing them the harder way. Thanks for the lesson."

R37: "This is very good and can save valuable time."

Comments from Students from Faculty of Science:

R3: "The system is good especially to the students who are carrying out their final year projects. I believe the training should be extended to be made compulsory to all university students or offered as a General Education Course."

R38: "The information resource is an excellent source, it saves time and makes work much easier. It should be made available to the student community as soon as possible."

R40: "Very useful, efficient, can help many students. I think students should be made alert or try as much as possible to access it. It is very important in whatever field. And it's very effective for project usage."

R44: "The demonstration is relevant and personally I would highly recommend it to every student. If possible it should even be incorporated into computer skills course because it would greatly benefit students across all faculties. Keep up the good work."

Comments from Students from Faculty of Social Sciences:

R1: "The information resource is well articulated and very easy to understand."

R2: "I think the system is a good initiative which should be introduced to students as early as year one. It would be a useful resource for our assignments and projects. Some of us struggled with our projects while there was an easy way out."

R5: "The system is good and wish to sit down and learn more about it when I am alone. My PowerPoint® presentation will be better made and presented. As for my research report, I will be able to do it in less time than before. Thanks!!!"

R14: "I wish the course was introduced earlier especially at first year level. It is very useful in research proposal writing and final research projects."

R21: "Brilliant!!! It's a time saver."

R22: "The whole exercise was really innovative and I wish that an on-going education for all students in the university will encompass the skills we learnt today. I really appreciate effort to input these excellent, priceless skills into my life as I am graduating from the University of Botswana."

Some results from the evaluation of the prototype design are as follows:

i. Over 90% of the students were satisfied with the functionality of the system.
ii. In terms of control, 98% of the students agreed that using the system will accord them greater control over the ICT skills needed for their research project.
iii. Over 90% of the students agreed that the system will enable them to complete their research project more quickly.
iv. On the issue of support, 89% of the students agreed that the system will support critical aspects of their research project task.
v. Ninety-eight of the students agreed that the use of the system will increase the effectiveness of ICT tasks for their research project.
vi. Ninety-one percent of the students agreed that using the system would allow them to accomplish more work than will otherwise be possible, using the system will make it easier for them to write their report.
vii. In terms of its usefulness, 98% of the students agreed that use of the system will significantly increase the quality of their report and that they will find the system useful in their work.
viii. Ninety-one percent of the students agreed that the system has been designed with an understanding of their ICT skills need.
ix. Overall, students felt that the ICT information resource fitted into their task and that they could easily follow the steps.

Discussions and Conclusions

The purpose of the prototype development aspect of this research was to design and develop an ICT information resource for final year research projects. This section addresses the research questions in the design and development part of the research. The design, developmental aspect sought to examine the functional requirements for the ICT skills information resource, students' perceptions of the task-technology fit of the prototype system as well as students' perceptions of the potential usefulness of the prototype system.

Like any information system, the success of learning object technology also depends on user satisfaction and acceptance (Lau & Woods, 2008). This section discusses the evaluation based on the three research questions.

RQ1: What are the functional requirements for the ICT skills information resource?

It is important that the functionality of learning objects and any interactions to be used should be carefully designed as interactivity is influenced by the degree of learner control as well as the availability of the functional features that encourage users to actively learn (Lau & Woods, 2008; Robertson, 1998; Stoney & Wild, 1998). The thematic analysis of students' use, evaluation and question and answer session on the ICT resource revealed three functional requirements:

- The system shall provide appropriate questions and answers that will help in areas where ICT skills are needed for research
- The system shall provide appropriate view for the user to read the answers to the questions
- The user shall be able to search the contents of the modules and select appropriate ones that answer their questions.

All these requirements were met in the ICT information resource design. Students from three (3) out of the four (4) faculties rated their satisfaction of the functionality of the system at 100%. Only students from the faculty of Humanities rated their satisfaction at 82.3%.

RQ2: What are the students' perceptions of the potential usefulness of the prototype system?

The students highly regarded the perceived usefulness of the ICT information resource. Eight out of the nine items related to perceived potential usefulness were rated at over 90%, while only one item was rated at 88.6%. Except for students' from the faculty of Humanities, all the students agreed that using the system will give them greater control over the ICT skills they need for their research project. They also agreed that the system will enable them to complete their research project more quickly and will support critical aspects of their research project task. Furthermore, they agreed that using the system will increase the effectiveness of ICT tasks for their research project. It will enable them to accomplish more work than would otherwise be possible, and the system will make it easier for them to write their report. They also all agreed that the use of the system will significantly increase the quality of their report and that they would find the system useful in their work.

According to Stokes (2001) a high level of user satisfaction reflects the users' willingness to accept and continue using technology. This is also confirmed by Lau and Woods (2008) who predict that behavioural intention to use is jointly determined by a person's attitude toward using the system and its perceived usefulness. Therefore, behavioural influence determines actual use. It is expected that with the high level of their satisfaction with the perceived potential usefulness, students will both accept and use the ICT information resource.

RQ3: What are the students perceptions of the task-technology fit of the prototype system?

Over 90% of the students agreed that the system has been designed with an understanding of their ICT skills need. In 9 out of the 10 items related to task technology fit, 85% of the students agreed to the Task Technology Fit. From the discussion with the students and their narrative comments, it can be inferred that some students from the Faculty of Business wanted SPSS® skills included, which was not included in the ICT information resource because the need was not general to all the faculties. One of the goals set out at the beginning of the research was that the contents of the resource should be useful to the six faculties. However, overall, students felt that the ICT information resource fitted into their task and they could easily follow the steps. Lau and Woods (2008) in their model proposed that educators and instructional designers of learning objects should ensure compatibility between learning objects and users' need in order to enhance the adoption of learning objects' for individual learning. It is therefore expected that with the high level of fit between the task and technology, the ICT information resource will be adopted for use by the students.

Based on the evaluation and comments from the students, the design of the information resource can be adjudged highly successful. The Information Resource with the use of adult learning principles has contributed to this success. The perceived potential usefulness and task technology fit were quite high. Over 90% of the students in the evaluation team agreed that the system has been designed with an understanding of the ICT skills they need, they were satisfied with the functionality of the system and will give them greater control over the ICT skills they need for their research project, and they felt the system will enable them to complete their research project more quickly and increase the quality of their report. It is therefore expected that with the high level of their satisfaction with the perceived potential usefulness, and Task Technology Fit, the ICT information resource will be accepted, adopted, and used by the students.

The development of the prototype, which involved the fusion of several current resources and the use of adult learning principles, has provided relevant information that will help the students to do their research with ease. The ICT skills will empower the students to handle more complex tasks and motivate them to use more advanced features of the packages. The information resource will help students to acquire the desired ICT skills as well as develop self-directed lifelong learning skills. The resource will also aid making decisions about the appropriate level of computer training that students require. These ICT skills will empower the students to handle more complex tasks and motivate them to use more advanced features of the packages. The developed resource is expected to lead to the reduction of the time spent in producing reports and ultimately result in the production of research of better quality. The same prototype could serve as a resource for academic departments as well as meet the ICT needs of various faculties, graduate students and academic staff in the pursuit of their research.

The study was confined to determining general ICT skills required in final year research project and providing a prototype resource to meet such needs. It did not cater for ICT skills required for other purposes. Information technology changes rapidly and may have an effect on the results of the study since the research project took about three years. However, in the process of the research, changes were catered for in order to minimize the effect of the rapid change.

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Biography

Oduronke T. Eyitayo, PhD is currently a Senior Lecturer in the Department of Computer Science, University of Botswana. She has a B.Sc in Computer Science, Masters in Information Science and a PhD in Information Studies. She is interested in making ICT resources easy and simple to use for the end-users. She has been involved in teaching, training, writing materials and developing resources that enhance end-user experiences on the use of computing devices. She has published articles addressing different issues in Information Technology and presented papers at several conferences.

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Developing Cross-Cultural Awareness in IT: Reflections of Australian and Chinese Students

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Executive Summary

To succeed within the increasingly global context of their work environment, today's IT professional needs to be equipped with both cutting-edge technical skills and a strong repertoire of "soft" skills. An important and often unrecognized soft skill is an appreciation of how various IT issues impact upon different peoples and what constitutes an acceptable professional practice in different societies.

Australian IT students need to develop an appreciation of the impact of culture on IT issues in their own society and beyond. In particular, students require a global perspective on the impact of culture on responses to ethical dilemmas, security challenges, and privacy threats in the practice of their profession. The challenge for IT educators is how best to develop cross-cultural professional awareness in students.

This article reports on the inaugural implementation of an innovative approach aimed at developing cross-cultural awareness in undergraduate IT students. The approach comprises formative assessment tasks based on real-life IT scenarios and work in culturally mixed students teams while immersed in a culturally different society (Australian students in China in this case). The article outlines the reflections of the Australian and Chinese students participating in the experience and comments on the perceived effectiveness of the approach. Student reflections pertain to two themes: one on privacy and social freedom, and another on cross-cultural awareness. The reflections endorsed the benefits of the approach reported in this article and, in themselves, are a further encouragement for planned future exchanges.

Keywords: cultural awareness, information technology, professional skills, Australia, China.

Introduction

In Information Technology (IT) roles, there is an increasing emphasis on employees having "soft skills", i.e. people skills. While technical knowledge is essential, it is also important for IT professionals to be able to relate to the requirements of the users, manage projects, work with teams, and, often, work in a global professional context. According to the 2006 report of the Department of Communications, Information Technology and the Arts (DCITA) (2006), titled "Building Australian ICT skills", IT will continue to be increasingly embedded in business, and IT professionals will need to work in multidisciplinary

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teams which will require problem solving abilities, negotiation skills, and a capability to understand the needs of customers and project colleagues. Moreover, the report indicates relationship management will grow as one of the main areas of expertise of the IT profession. This will require IT professionals to acquire skills in “managing intangibles, negotiating among different parties and coordinating outcomes among geographically distributed parties with different work agendas and cultures” (DCITA, 2006, pp. 51-52); this will include managing relationships between overseas service providers and domestic customers.

Globalization, a reality of the 21st century, is enabling the progressive merging of international markets and the dissolution of economic borders (Altback & Knight, 2007; Hutchings, Jackson, & McEllister, 2002). Thus, graduates are likely to work offshore in their future professional lives so it is incumbent on education programs to prepare students to undertake job assignments anywhere in the world.

Mobility is another growing trend among the IT workforce (Joseph, Boh, Ang, & Slaughter, 2012). Australian IT professionals are expected to travel to work overseas and IT professionals born overseas come to work in Australia; they currently account for 40% of the national IT workforce (Multimedia Victoria, 2010). Hence, there is an even more compelling need to incorporate international perspectives and cross-cultural awareness into the development of professional skills in students (Forsey, Broomhall, & Davis, 2011). However, how should this cross-cultural professional awareness be embedded in IT curricula? Research suggests that study abroad experiences help expand student outlooks and increase their intercultural competencies (Dwyer & Peters, 2004; Forsey et al., 2011; Nunan, 2006).

Many traditional IT education programs expend effort in developing professional awareness within their home culture but rarely expose students to the professional norms of other societies. This is particularly true for Australian students who are trained within a traditional Western education system, yet they are likely to have professional lives within the culturally diverse Asia-Pacific rim. Thus, students who gain awareness of the region’s cultures in a meaningful professional experience would be most advantaged in their job readiness.

This article suggests an answer to the important question of how best to develop cross-cultural professional awareness in students. It outlines an approach to the development of this awareness through a learning strategy which examines Western and Eastern cultural responses to IT case studies. The article describes the first implementation of the approach at Victoria University in Australia with a cohort of IT students in 2012 conducted in collaboration with a university in China; it includes the Australian and Chinese students’ reflections on the benefits of their shared learning experience.

The Approach

Most IT programs include several units of study designed to incrementally build soft professional skills in their students: skills such as teamwork, verbal and written communication, and networking. The demands of globalization require that cross-cultural awareness be included as a necessary component of the suite of soft skills to be developed in the delivery of an IT program.

When designing IT curricula, a suitable framework unit should be identified to target cross-cultural awareness development. In the instance outlined in this article, the core unit of study selected was “Security, Privacy and Ethics”, within the Bachelor of IT (Network and Systems Computing) at Victoria University. The unit introduces topical, contemporary, and often controversial issues, and it affords students the opportunity to examine ethical dilemmas, security challenges, and privacy concerns brought about through the use of IT in society. In particular, the unit highlights that IT technologies, systems, and applications are no longer constrained by national borders, and it includes case studies where strong cultural differences can influence responses to IT issues.

A feature of the unit is the examination of professional IT issues within Australian society and, for comparison, a culture within the Asia-Pacific rim. The Asia-Pacific region's cultures form a relevant pool of societies for Australian students to make comparisons with their own, particularly as the economic growth of the region is being fueled by the spread of IT (Television for Education, 2012) and many Australian IT graduates are likely to find themselves working there. As an emerging political super power within the region, China is of particular interest; it is one of Australia's major trading partners and the growth of the Chinese middle class is fuelling demand for Australia's technical expertise.

There are differences between some of the cultural norms of Australia and China; what may be viewed as harmless information sharing in one country, might be regarded as privacy or security concern in the other (Feng & Hughes, 2009). In China, private data is data that others should not know about, such as information about family property or one's love life. In Australian and other Western cultures, the list of items considered to be sensitive personal data is much more comprehensive and can include salary, religion, a woman's age, marital status, sexual orientation, and political preference.

There is a large body of literature supporting the use of assessment to drive learning outcomes (Boud & Falchikov, 2007). Formative assessment provides opportunities for students to learn through the process of undertaking an assigned task, and we use it to encourage students to examine their own understandings of IT in the Australian and other societies. An example in its simplest form could be an assignment requiring students to research IT scenarios in another society; students would be expected to identify the security issues and privacy concerns and to discuss differences between the response taken in the other society and the students' own. Ideally, students should gain firsthand exposure of the target society whilst completing their assessments.

Thus, the development of the proposed approach to incorporating cultural perspectives into the IT curriculum was driven by the intention to achieve the best possible outcome by combining formative assessment with immersion in a regional Asia-Pacific culture. It capitalizes on much educational research advocating the use of working in culturally mixed teams when undertaking groupwork (Kimmel & Volet, 2009; Strang, 2010; Trahar & Hyland, 2011). The approach, as detailed in Venables, Miliszewska, and Tan (2012), incorporates four integral elements:

1. **formative assessment tasks** where the assessment tasks guide learning experiences that promote reflections of the two contrasting cultures, one western and one eastern;
2. **a real-life IT context**, where students examine real-life IT situations and analyze the issues and differences between the responses of their own society and the different society;
3. **immersion within the target society** where Australian students participate in a short-term study visit to a university within a contrasting society; and,
4. **working in culturally mixed teams** –Australian and foreign students work together on the assessment task.

For the first implementation of this approach, China was identified as a target society. For Australian students, China is an intriguing case study of contrasts to examine; unlike Australia, it has a long cultural history and a political system that tends to control access to online information. The formative assessment task was to be centered on one of several IT scenarios and it was broken into two components: the first part to be conducted in Australia, and the second part to be completed together with Chinese students while on a study visit in China.

For the first component of the assessment, Australian students were asked to read and discuss one of several controversial situations using current IT case studies concerning security challenges, threats to privacy, and ethical issues within a western context. From their discussions, students distilled the issues, explored the various aspects, commented on possible solutions, and decided an appropriate response in their own society. For the second component of the assessment, a study visit was organized so that Australian and Chinese IT students could gain a more comprehensive perspective of the role of IT in their respective cultures. A structured program of activities ensured that all students had opportunities to discuss security and privacy issues, to engage in teamwork, to have practice in verbal and presentation skills, and network across cultural barriers. Any selected scenario needed to be culturally sensitive and avoid topics that could be considered inappropriate or too contentious for student discussion, for instance, some topics on ethics and professional behaviors, particularly if they were related to government policy. Close liaison with the Chinese host academics ensured the selection of appropriate scenarios.

The Implementation

The first study visit to implement the proposed approach was undertaken in April, 2012 when Victoria University students travelled to our partner institution, Shanghai Maritime University, in China for ten days. The visit offered a prized opportunity for the Chinese students selected to participate in the project to practice communication skills with native English speakers using the case study scenarios as a focus. English language competency is highly regarded by Chinese academics and their students. Academics at the host university selected for the project their most competent student communicators from a pool of eager candidates. Prior to the visit, we sent to our partner institution a set of case studies so that the participating Chinese students could examine those in preparation for our visit.

Our visit commenced with two days of local orientation activities for the Australian students; the first day was an organised tour of local cultural attractions, and on the second day, students were free to explore on their own. On the third day, the Australian students travelled to Shanghai Maritime University to meet their Chinese counterparts. They participated in local campus orientation and formed cross-cultural teams of four students, two Australian and two Chinese, to undertake the second component of the assessment task. Over the following days, teams distilled the issues, discussed possible solutions, and decided the appropriate response for their own society.

Each team discussed only one of several IT scenarios that had been previously assigned. The discussion centered on how the situation raised by their scenario would be resolved in Australia and in China. As an example, "The Football Broadcast War" case study involved the use of playback technologies to rebroadcast 'live' football games, as described in a newspaper article (http://www.footballnation.com.au/afl/afl-issues/the-football-broadcast-war/). In this case study, Optus, a telecommunications company, taped and rebroadcasted matches on a few seconds delay allowing its subscribers to access live football game coverage free of charge. Telstra, a competitor telecommunication company, claimed that Optus had infringed their copyright by providing Optus customers a free viewing of live football matches. Telstra had paid $153 million for exclusive rights to the broadcasts. Discussions between the Australian students and their Chinese counterparts in examining the "The Football Broadcast War" case study revealed differences in how both cultures viewed the issue. Australian students felt that there were two separate services being supplied. Telstra customers were paying for a premium and immediate service. Optus customers had a lesser service in the small time delay, and therefore they should not be charged for the service. According to the Australian students, Optus had not infringed Telstra's copyright but rather Optus was simply taking advantage of playback technologies to provide the service for free. In addition, Australian students saw attempts to restrict the use of playback technologies as a dangerous step towards censorship. In contrast, Chinese students saw the matter quite differently.

They argued that Telstra had paid for the exclusive rights to football games, regardless of the broadcast technologies being used. Having made such a large investment, Chinese students believed that Telstra needed protection from the government to ensure their financial interests; they had difficulty in understanding how Telstra's rights were not automatically given protection in Australia.

All teams prepared reports on the respective case studies and their discussions. Each team gave a joint presentation on how their IT scenario would be handled in Australia and in China. In their talks, students highlighted the commonalities and differences in the ways their own societies would respond to the scenarios. As each group had a different case study, much was learnt about the role of IT in both societies, as the presentations elicited many questions and comments from the audience of Chinese and Australian students. The assessment panel, composed of both Australian and Chinese IT academics, found all the final presentations to be of an exceptionally high standard and all agreed that the assessment task had been an enriching learning experience for all.

For the Australian students, living on campus and eating local food whilst enjoying the genuine friendship of their Chinese buddies was as much of a learning experience as that prescribed by their assessment. While staying at Shanghai Maritime University, the on-campus experience was quite different to that experienced in Australia. Shanghai Maritime University is a specialist Chinese university devoted to studying marine logistics and technologies and is located many kilometres away from the Shanghai city. Victoria University is located in the capital city, Melbourne, and most of its students commute daily from the surrounding suburbs. All participants expressed their thorough involvement and enjoyment in the cultural exchange and they have reported on the many lessons learnt through the experience.

Student Reflections

It is very difficult to gauge the extent to which cross-cultural awareness has been developed by this assessment; literature does not point to any objective measure that could be used and such measures are yet to be developed. As well, it is often the case that students who opt to participate in cross-cultural experiences have difficulty in articulating what they have learnt from the exchange (Forsey et al., 2011). To help assist students in their contemplations of the activities and to "measure" the development of the cross-cultural awareness in some way, all students, Australian and Chinese alike, have been asked to reflect on their experiences of the study tour and the joint assessment task. Reflective practice of learning experiences has become increasingly popular in all areas of education as a mechanism to encourage deeper learning through critical reappraisals (Light, Cox, & Calkins, 2009; Reynolds, 2011).

A selection of the student responses, reproduced verbatim, is presented for illustration. Collectively, we noted two emerging themes: one on privacy and social freedom, and another on developing cross-cultural awareness. We have organised the student responses according to these themes and each paragraph comes from a different student; responses have been prefixed as (Aus) for Australian students, and (Chn) for Chinese students.

On Privacy and Social Freedom

(Aus) *Having only experienced life in Australia before this trip, the study tour was a real eye opener for me. I learned quickly that the way things are done overseas are quite different to how we do them at home. I gained an understanding of Chinese culture and came to realize that we take for granted some of the things that are foreign to the Chinese. An example of this is social freedom, we are allowed to speak our minds on internet forums and social networking sites whereas all of this is policed by the Chinese government.*

(Chn) *Through the week's contact, I discovered that our Chinese way of thinking and our habits and the purpose of education are very different from the Australian way.*

(Aus) *This trip has helped me pick up on the more subtle aspects of the Chinese way of thinking and Chinese culture. There are many things I experienced that I don't feel like I could have expected beforehand or have learnt about without being there and living through the experiences I have now had. An excellent example of this was when first meeting my [Chinese] buddy after she had finished taking me on a short tour of the campus we had to go up to my room to pick something up. Once at the foot of my door I opened it up and walked inside to gather my things only to notice that she was waiting outside in the hallway. I motioned for her to come in but she wouldn't without asking me first three times if it was okay if she entered. In Australia I had never found this kind of privacy to be a very big deal but apparently in China it was taken pretty seriously to let someone enter your room.*

(Aus) *I learned that government also plays a massive part in Chinese culture. They mould the society into something quite different from that in Australia. It seems that people don't really receive any help from the government in the form of financial aid and I believe that it is because of this, people seem to have more drive to succeed.*

(Chn) *My topic was about Facebook's facial recognition system. Everyone began to talk about this topic. I found it strange but interesting. We exchanged out thoughts on the topic, and after the exchange we came to know our topic and become friends.*

(Aus) *In contrast to this fact when undertaking the preparations for the presentation we found out that when it comes to social networks and things to do with the internet the Chinese tend to care very little about privacy.*

On Developing Cross-Cultural Awareness

(Aus) *I have never travelled before and travelling overseas and exploring different cultures has never been high on my priority list. Travelling to China has given me some perspective as to what goes on around the world and how things can be so different to Australia. The difference between our cultures and having to learn and adapt to a different one was an experience I'll never forget, something I definitely want to experience again.*

(Aus) *I feel that I have had a deeper cultural connection with China. Spending most of my time with a group of students from Shanghai Maritime University in China has given it a more authentic feel as I know that I am truly experiencing the country in the same way that they themselves do on a daily basis. This kind of experience is hard to come across.*

(Chn) *It has changed my world view and how I see life. Now I have a better understanding of the outside world and how people of the same ages live, and I believe it has an impact on my outlook on life.*

(Aus) *I encourage people to interact with other people so we can remove the barriers between many race and understand their ethics background, because what I have learnt so far is what we think as Australian is not right it is right do to in China, and if we have a briefed* *or general idea about other people ethics we wouldn't have to underestimate people again and all will live happily.*

(Aus) *I went in, much like the other students with little knowledge on the Chinese culture, perceptions only created by what the news and television had to offer so I was a little skeptical, but the experience was an eye opener with their population so high their business seems extremely large scale in comparison to that of Australia's trade.*

(Chn) *We just learn everything we are asked to learn in China, but we often ignore the importance of what we need to learn.*

(Aus) *This study tour has benefitted my future career opportunities by giving me insight into how things are done overseas. I believe that this insight has improved my understanding of how much cultures can differ and feel that because of this, I will now be better in any field which I decide to go into once graduating, thanks to this Study Tour.*

(Aus) *I've also gained experience working on a project with people in another country and this has given me a better understanding on what to expect when working internationally.*

(Chn) *To be honest, we benefit a lot from working with the Australian students, not only some knowledge, but also understand how to study.*

(Aus) *The Chinese have a lot of morals and respect for their culture and age differences. If you are older and or a higher status, you will be greeted with higher respect. I saw this when I was at the university when students greeted their teachers and their parents.*

Final Remarks

For Australian and Chinese IT students, the development of professional skills, including cross-cultural awareness, is as crucial as the development of technical skills. This article reported on the inaugural implementation of an approach aiming to enhance student cross-cultural awareness and "soft skill" development through a bi-national study experience supported by a contextual study of real-life IT scenarios.

Students participating in the study experience reported favourably on the impact of experience on their understanding and appreciation of different cultures in general, and the influence of culture on assessing and responding to IT related problems. Student responses seem to indicate an improved understanding of each other's culture and some shifts in perceptions and beliefs.

Student reflections provided a qualitative endorsement of the benefits of the approach and pointed out the pivotal role that the immersion within the target society and the opportunity to work in culturally mixed teams played in achieving the desired learning outcomes. This is a further confirmation that the use of formative assessment tasks and real-life IT scenarios is helpful in developing cultural awareness in students, but immersion and close cross-cultural contact have the potential to maximize the learning benefits.

Following the positive feedback on the study experience from students and academics, in Australia and China alike, it was considered worthwhile to embed the experience in the curriculum in future years. It was agreed that, to ease the financial demands on the participants, the study tours would alternate from year to year, or, if funding could not be secured, a virtual solution would be deployed. Consequently, in 2013 a cohort of Chinese participants from the Maritime University will come over to Victoria University.

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Enhancing Students' Interest in Science and Technology through Cross-disciplinary Collaboration and Active Learning Techniques

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Executive Summary

Twenty-nine rising high school 12th grade students participated in a 4-week summer program designed to increase their interest in science and technology. The program was a blend of hands-on biology, chemistry, and technology modules that addressed the global issue of obesity. Student groups developed websites to address obesity in one of five countries – Egypt, Mexico, Puerto Rico, United States, and the United Kingdom. Three university professors, two from Computer Information Systems (CIS) and one from Biology, formed a partnership to inspire high school students to embrace technology that conveyed scientific concepts about obesity. Survey results showed an increased interest and aptitude in science and technology. After our program, 68% of the students indicated that they plan to pursue a major in science, technology, engineering, and mathematics (also referred to as STEM majors). Of those students who indicated an interest in STEM disciplines, the largest numbers noted their interest in the following majors: biology, engineering, computer science, computer information systems, and chemistry. At the end of the summer, 85% of the students agreed that the summer program activities helped them to better understand how the science and technology modules from the FUTURES/T.A.G.S. summer program were connected to obesity.

Keywords: Active Learning, Cross-Disciplinary Collaboration, Science, Technology, STEM, STEM careers; High School Summer Program, Interdisciplinary Programs

Introduction

> *"Achieving the goal of scientific and technological literacy requires more than understanding major concepts and processes of science and technology. Indeed, there is a need for citizens to understand science and technology as an integral part of our society. Science and technology are enterprises that shape and are shaped by human thought and social actions."* (Bybee & DeBoer, 1994, pp. 384)

Today's real world problems often have both scientific and technological aspects. Science tries to understand the natural world while technology tries to solve practical problems. Technology can expand our capacity to understand and control the natural and human-made environment. Students must learn to use technology as a tool to help understand science and increase creativity in scientific investigations. The challenge of

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science education is to prepare students to become scientifically and technologically literate decision-makers and problem solvers.

Students do not learn and retain solely by reading or hearing lectures about science, they must experience science. Science experiences should be connected to students' everyday life as well as the science and technology related social issues with which their local communities, nations, and all humanity struggle (Solomon & Aikenhead, 1994).

A collaborative program between Fostering Undergraduates through University Research and Education in the Sciences (FUTURES) and Technically Aspiring Global Students (T.A.G.S.) provided 29 students with an innovative blend of science and technology to better prepare them for science, technology, engineering, and mathematics (STEM) majors in college. The program set out to accomplish this goal through the use of active and collaborative learning that enabled students to access, analyze, interpret, synthesize, apply, and communicate information regarding global obesity.

FUTURES is a four-year science education program designed to provide innovative math and science enrichment experiences for a cohort of students as rising 11th graders in high school through the end of their freshmen year in college. During the first year's summer program, students participated in SAT preparatory workshops coupled with science modules in biology, chemistry, and earth science. Although it enhanced the students' content knowledge, test-taking strategies, and how to perform basic laboratory procedures, the post summer assessment revealed that there were no significant increases in the students' interest toward careers in STEM. In an effort to increase students' interest in STEM careers, FUTURES modified its summer program for Year 2 to include more hands-on biology and chemistry activities as well as a technology component. To implement the technology component, the FUTURES program collaborated with T.A.G.S., an outreach program designed to inspire high school students to embrace technology while encouraging their academic, social, and personal development.

The FUTURES/T.A.G.S. summer program theme was "Addressing Global Obesity". This four week summer program blended hands-on biology and chemistry modules with a technology component that introduced students to HTML coding. Students were divided into five (5) teams in order for them to collaborate, with each team looking at the real world issue of obesity in their given country (i.e., Egypt, Mexico, Puerto Rico, United Kingdom, and the United States). The student teams used active learning to create websites to address obesity issues and identify possible solutions integrating what they had learned in the aforementioned science modules.

The rest of this paper is organized as follows. In the next section we provide a literature review on the status of STEM in the U.S. along with active and collaborative learning. Based on this foundation, in the subsequent sections we discuss our innovative approach, hypotheses, methodology, results, discussion, and finally the conclusion.

Literature Review

Science, Technology, Engineering, and Mathematics (STEM)

> *"Today, more than ever before, science holds the key to our survival as a planet and our security and prosperity as a nation. It's time we once again put science at the top of our agenda and work to restore America's place as the world leader in science and technology."* ~ President Barack Obama

In November 2009 President Obama launched the "Educate to Innovate" campaign to motivate and inspire young people across the country to excel in STEM. A growing number of jobs require STEM skills and America needs a world-class STEM workforce to address the "grand challenges" of the 21st century, such as developing clean sources of energy that reduce our dependence on foreign oil, discovering cures for diseases, and addressing health issues such as obesity. Success on these fronts will require improving STEM literacy for all students, expanding the pipeline for a strong and innovative STEM workforce, and greater focus on opportunities and access for groups such as women and underrepresented minorities (White House, 2009).

The National Academies' report (2006) expressed their concern about the declining state of STEM education in the United States. In their report the committee developed a list of ten actions that federal policy makers should take to advance STEM education in the United States to ensure competitive success in the 21st century. Two of their top recommendations were to:

1. Increase America's talent pool by improving K-12 science and mathematics education; and
2. Enlarge the pipeline of students prepared to enter college and graduate with STEM degrees.

Active Learning

If you tell me, I will listen.
If you show me, I will see.
But if you let me experience, I will Learn.
~ Lao-tse, 5th Century B.C. Chinese Philosopher.

Active learning, also known as discovery learning, emphasizes the intrinsic motivation and self-sponsored curiosity of students who fashion content and are actively involved in its formation (Bonwell & Eison, 1991; Leonard, 2002). In his classic article, Bruner (1961) states that learners are more likely to remember concepts if they discover them on their own, apply them to their own knowledge base and context, and structure them to fit into their own background and life experiences. In active learning the instructor serves as a catalyst directing projects that center around solving a problem. Students that are actively involved in the analysis, synthesis, and evaluation of content gain a better understanding of the information than they would otherwise have through passive, instructor-centric learning.

In active learning, the mode of instruction must allow the students to create authentic, hands-on learning experiences in order to learn new information. In active learning students become participants in their own education, increasing the likelihood of retention. The elements of active learning include talking, listening, reading, writing, and reflecting (Chickering & Gamson, 1987; Meyers & Jones, 1993). These elements, which involve cognitive activities, allow students to clarify, question, consolidate, and appropriate new knowledge. Characteristics of active learning include focusing on developing skills and higher order thinking (Bonwell & Eison, 1991).

Although there are mixed results in the literature concerning the impact of active learning (Drake, 2012), there are numerous examples of how active learning improves student learning outcomes (D. Johnson, Johnson, & Smith, 1998a, 1998b; Springer, Stanne, & Donovan, 1999). The use of information technology as a tool to help facilitate active learning has also been shown to impact student learning. Blumenfeld et al. (1996) used online resources from the Internet to enhance the science learning activity of middle school students while Hmelo-Silver, Duncan, and Chinn (2006) used software tools in the instructional processes.

Collaborative Learning

Collaborative learning is defined as a method of learning in which students are placed in teams of two or more people to explore a significant question or create a meaningful project through capitalizing on each other's resources and skills (Chiu, 2000; Dillenbourg, 1999; Dillenbourg, Baker, Blaye, & O'Malley, 1996). The benefits of collaborative learning include the development of interpersonal skills (Jun & POW, 2011), active involvement in the teaching/learning process (Lafifi & Touil, 2010), enhancement of critical thinking (Cheong, Bruno, & Cheong, 2012; Gokhale, 1995), learning conflict resolution and taking ownership of the project/results (R. T. Johnson & Johnson, 1986). In the following section we discuss the innovative approach used to structure the summer program.

Innovative Approach

The FUTURES/T.A.G.S. summer program was developed to assist in promoting President Obama's "Educate to Innovate" campaign through inspiring students to major in STEM disciplines. The FUTURES/T.A.G.S. summer program, whose theme was "Addressing Global Obesity", was unique because it was designed as a hands-on program that encouraged students to experience science and technology through addressing the real world issue of global obesity. The summer program was designed utilizing these fundamental concepts: 1) addressing a real world problem, 2) cross-disciplinary collaboration between science and technology, 3) hands-on activities, and 4) team development of websites.

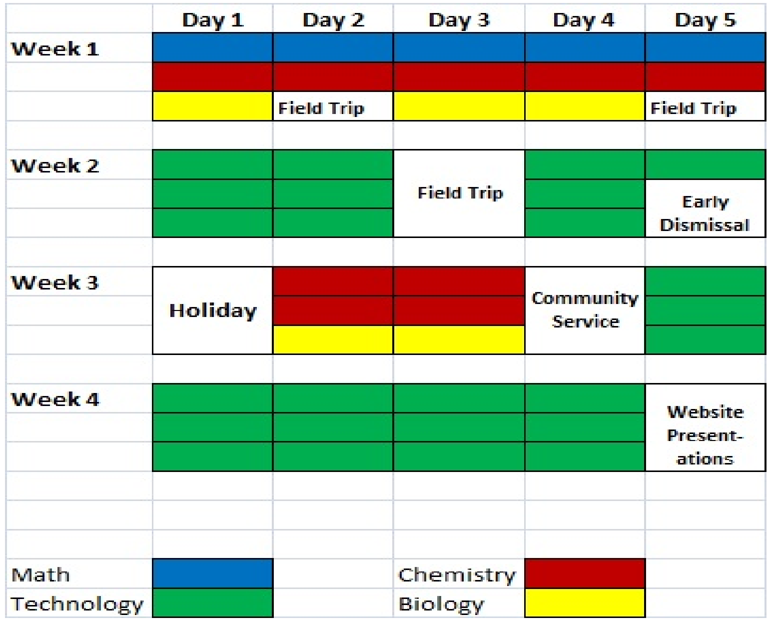
We provided this cohort of 29 students with opportunities to increase their insight into, and appreciation of, the investigative process by connecting science and technology to their daily lives during a 4 week summer program. These students in turn used active and collaborative learning to research and address the real world problem of obesity from their country's perspective. The countries (i.e., Egypt, Mexico, Puerto Rico, United Kingdom, and the United States) were chosen from a February 2010 report of Global Prevalence of Adult Obesity.

Students were organized into teams of 5-6 members to allow them to collaborate on the development of the country websites. The teams applied their experience and knowledge across four content areas: biology, chemistry, mathematics, and technology (See Table 1 for more details on the program schedule). These activities allowed students to use active learning techniques and group discussions to understand more about obesity and strengthen their critical thinking skills. For example, in the biology and chemistry modules, students learned how to use basic scientific equipment such as micropipettors and centrifuges to isolate and analyze fat content. The mathematics and technology modules allowed students to use spreadsheets to collect, record, and display their data about nutrition, diet, and exercise. The culmination of these activities was the development of a website for each student team to present their findings on and interpretation of obesity. The students had nine days of daily instruction to build their team website. Building the websites allowed the teams to display the new knowledge learned and develop a medium to reflect and express their new knowledge in a creative way.

In order for students to develop their websites the software and resources resided on the Virtual Computing Lab (VCL). VCL is cloud computing technology that allows an "image" of software applications and resources to be used anytime and anyplace as long as students had access to the Internet.

Utilizing collaboration in the FUTURES/T.A.G.S. program allowed us to design a program to integrate our students' experiences in science and technology and help them investigate the "real world" health problem of obesity. In the following section we discuss the hypotheses that were used to evaluate the summer program.

Table 1: FUTURES/T.A.G.S. Schedule for the 2010 Summer Program



Hypotheses

Three hypotheses were developed in order to evaluate the effect of the summer program. The first hypothesis was developed to determine what impact the program would have on the students' selection of STEM majors. The hypothesis states:

H1. The summer program would positively impact the students' overall interest in one of the STEM majors.

The second hypothesis was developed to survey the students' perception of their knowledge acquired in the science component. The hypothesis states:

H2. Student's perception of their competence in science research skills will increase as a result of the summer program.

The third and final hypothesis was developed to test the increase in content knowledge and skills that the students gained in the technology component of the program. The hypothesis states:

H3. Student's content knowledge and skills in technology will increase as a result of the summer program.

In the following section we will discuss the methodology used to evaluate the three hypotheses.

Methodology

We developed several instruments to capture qualitative and quantitative data on the students as it related to their knowledge and perception of science and technology. The pre- and post- surveys were administered to determine the students' perception of science skills, intended college majors, and overall interest in science and technology. The pre- and post- web assessments were administered to determine whether the students increased their knowledge of web development and technology.

The pre- and post- surveys consisted of a total of 34 questions. The questions were grouped into the following categories: perception concerning science, likes/dislikes regarding the program, computer knowledge, STEM careers, and science abilities. Fifteen questions evaluated the students' perceptions regarding interest and enthusiasm relative to the science modules for which a 5-point Likert scale (i.e., strongly disagree, disagree, neutral, agree, strongly agree) was used. Four open-ended questions allowed students to comment on likes or dislikes regarding the program. Eight questions asked students perceptions regarding their computer knowledge. The last 7 questions asked students their interest in STEM careers and their perception of their scientific competence and reasoning abilities.

The pre- and post- web development assessments were administered to document the participants' growth in skills used to design and build websites. The pre-web development assessment consisted of 18 questions: three questions regarding their knowledge and experience with VCL and 15 multiple choice questions on HTML code and tags. The post-web development assessment consisted of 27 questions: 12 questions regarding their knowledge and experience with VCL and 15 multiple choice questions on HTML code and tags. In the next section we discuss the students' responses from the instruments used to test our hypotheses.

Results

Twenty nine students participated in this study (14 females and 15 males). The participants attended 13 different high schools in the Durham Public Schools system. Twenty-seven students were African-American, one Asian-American, and one Native-American. Ninety percent of the students were rising 12th graders and 10% were rising 11th graders (see Table 2 for student demographics).

Table 2: FUTURES/T.A.G.S. Student Demographics

Criteria	Males	Females	Total
Ethnicity			
African American/Black	14	13	27
Asian American	1	0	1
Indian	1	0	1
Classification			
Rising 12th graders	13	13	26
Rising 11th graders	3	0	3

Test of Hypothesis 1: Students' Selection of STEM Majors

The first hypothesis was developed to test the impact the summer program had on students' selection of college majors. Of the 29 students that were a part of the program, only 22 students (76% response rate) completed both pre- and post- surveys. Analysis of an open-ended survey question which asked students to list their intended major showed that only 12 of the 22 students (54.5%) were committed to studying a STEM area prior to the FUTURES/T.A.G.S. program. It is our hypothesis that the FUTURES/T.A.G.S. summer program had a positive impact on the students' interest in the STEM disciplines. Thus, the students' commitment to major in one of the STEM areas increased to 15 out of the 22 (68.1%) by the end of the program.

Furthermore, the FUTURES program continued to track the students throughout their matriculation into college. All 29 participants went to college with 80% enrolled in 4-year college and 20% in 2-year college. Seventy five percent of students have declared STEM majors which is a further increase from the 68.1% at the end of the summer program. These longitudinal results show the continuous impact that special programs such as FUTURES/T.A.G.S. can have on significantly increasing participants' interest in STEM majors.

Test of Hypothesis 2: Students' Perception of Their Competence in Science Skills

The second hypothesis was developed to survey the students' increase in their perception of the science skills acquired as a result of their participation in the summer program. The students rated their science skills between "Moderately Competent" and "Adequately Competent" on a 5-point Likert scale for 11 research process skills included on the surveys of which four of the skills were relevant to this study. The four skills were working with other science professional in a group, organizing data, preparing a scientific research poster/talk, and interpreting data. Table 3 shows the results between the pre- and post- surveys.

Table 3: Students' Competence Ratings Across Various Science Research Process Skills

	Pre Summer Program		Post Summer Program		Statistically Significant Difference (P<.05)
	% Competent	Mean ± Std. Dev.	% Competent	Mean ± Std. Dev.	
Working with other science professionals in a group	83%	4.29 ± .751	96%	4.44 ± .583	
Organizing data	96%	4.25 ± .532	88%	4.28 ± .678	
Preparing a scientific research poster/talk	80%	3.96 ± .841	72%	4.16 ± .850	
Interpreting data	60%	3.72 ± .678	80%	4.12 ± .726	P=.012

Table 3 shows that two of the four skills increased over the course of the summer. Those two skills were working with other science professionals in a group, which increased from 83% prior to the summer program to 96% at the end of the summer program (13% increase) and interpreting data (60% prior to the summer program to 80% at the end of the summer program (20% increase with a p-value of .012).

Test of H3: Students' Technology Performance

The third hypothesis was developed to test students' increase in content knowledge and skills in technology. For this we analyzed and summarized the pre- and post- web assessments to determine if there was an increase in proficiency of the students' technological skills. The results from our findings suggest a substantial increase from the pre- to the post- assessments. There was an average overall gain of 27.2% from the 24 students who took both the pre- and post-assessments, with two students receiving more than a 60% gain. Furthermore, of the 24 students, only one student showed a decrease in his/her score and one student showed no change. (See Table 4 for a detailed analysis of the percent change from pre- to post- assessments)

Table 4: FUTURES/T.A.G.S. Pre- and Post- Assessments Analysis

Percent Change from Pre to Post Web Development Assessments	Number of Students	Percent of Students
Under 0%	1	4.2%
0 - 9%	4	16.7%
10 - 19%	3	12.5%
20 - 29%	8	33.3%
30 - 39%	1	4.2%
40 - 49%	3	12.5%
50 - 59%	2	8.3%
60 - 69%	2	8.3%

In the following section we will further discuss the results and the overall impact of the summer program.

Discussion

Due to the different high schools, the students' science course selection and preparedness varied. All of the students had taken high school biology classes, but only a few had taken a chemistry and/or technology class. Their participation in the FUTURES/T.A.G.S. summer camp was a unique experience for them because it incorporated active learning activities and group participation in a collaborative environment to research and discuss the global societal issue of obesity. Through their research the teams proposed different causes of and solutions for obesity as it related to their country. For example, Team Mexico proposed that the lack of safe drinking water and the subsequent abuse of soda as a beverage at home and school was one of the several causes of obesity in that country. Another example was Team Puerto Rico, who discovered that cultural customs for food preparation (i.e., deep frying foods) along with the reduction of strenuous daily physical labor contributed to the rise of obesity in their country. There were numerous other examples where the teams demonstrated their ability to analyze the information to construct reasons and solutions for obesity rather than just simply repeating the information they found. Consequently, a major strength of the FUTURES/T.A.G.S. program was the teams' use of active learning to construct knowledge.

Student engagement was one of the other strengths of the program. Most of the students consistently attended the FUTURES/T.A.G.S. summer program and 85% of the students agreed that the in-class activities (i.e., laboratory modules and discussions) were interesting, relevant, and aided understanding. Moreover, 85% of the students agreed that the summer program instructors helped them to understand how the activities in the FUTURES/T.A.G.S. science and technology modules were connected to the common theme of obesity.

Students were also able to voice their opinion of the summer program by answering the following three open-ended questions:

1. What did you like most about the FUTURES/T.A.G.S. Summer Program?
2. What did you like least about the FUTURES/T.A.G.S. Summer Program?
3. Are there any changes that you would like to see made to the FUTURES Summer Program for next year?

There were 36 responses received from the students to the questions above. From the students' responses, four major themes emerged which covered 92% of the comments. The major themes are provided below with their accordance counts and percentage of all responses received followed by a selected response.

- Students valued the hands-on labs and felt that in helped them to better understand the material/subject areas as well as keep them engaged and interest. (Responses: 13 or 36%)

  "I liked the chemistry labs the most. It was very hands on and kept me interested the whole time."

- Students valued the collaboration component of the program. (Responses: 7 or 25%)

  "What I liked most about FUTURES is the web design portion that we did with T.A.G.S. I liked this part because we got to work in groups and team build."

- Need for clear understanding of the integration of the different components of the program as well as the same scheduling structure/organization. (Responses: 6 or 17%)

  "The organization at FUTURES can improve. T.A.G.S. gave us a day schedule and we knew exactly what was planned for us."

- Students were concerned that more time was needed to complete the deliverables (i.e. website). (Responses: 5 or 14%)

  "I did not like the limited amount of time to complete our website and posters. We were only given about four days to complete our websites and I felt we needed more time."

In the next section we provide concluding remarks and future research.

Conclusion

Through the FUTURES/T.A.G.S. summer program, high school students were provided the opportunity to increase their insight into and appreciation of the investigative process by connecting science and technology to their daily lives. This was accomplished by incorporating active learning exercises in a collaborative environment to research and discuss the global societal issue of obesity. In this summer program, the science modules were taught in the Science Building and the technology modules were taught in computer labs in the School of Business. During the four week summer camp, students were taught by university professors from the School of Business, Department of Biology, and Department of Chemistry. Undergraduate and graduate students from each of the respective disciplines served as counselors and were available to help facilitate instruction and provide additional help outside of class. Students were able to work outside of the dedicated instructional time by using VCL. Based on the high evaluation ratings that were received, we believe that the summer program succeeded in helping students continue to acquire knowledge and skills in biology, chemistry, and computer information systems. Survey data from the end of the summer indicated that 68.1% of students planned to pursue a major in STEM. Of those students who indicated an interest in STEM majors, the largest numbers noted that they were leaning toward the following majors: biology, engineering, computer science, computer information systems, and chemistry after the summer program. Additionally, the further tracking of the students throughout their matriculation into college showed that 75% of the students actually declared STEM majors.

Future collaborative summer programs will carefully examine and map the integration of STEM fields. We will also look for more ways to expose students to a variety of possible STEM careers as well as enhancing and strengthening the student engagement through active learning activities. We believe that this cross-disciplinary summer program played a major role in solidifying students' choice of STEM majors and can be replicated in other universities.

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Using Student e-Portfolios to Facilitate Learning Objective Achievements in an Outcome-Based University

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Executive Summary

Several researchers define e-portfolios as a digital collection of students' work accomplished throughout their time of studies in an academic program (Buzzetto-More, 2006; Love, McKean and Gathercoal, 2004; Paulson, Paulson, & Meyer, 1991; Siemens, 2004). E-portfolios can be a rich resource for students and faculty. Students learn to identify and reflect on their learning experiences and show accomplishment of learning outcomes. Faculty members provide students with feedback and guidance to help them accomplish these learning outcomes. In this study student e-portfolios consist mainly of a collection of project-based activities that provide students with opportunities to demonstrate mastery of skills and abilities. The College of Technological Innovation (CTI) has been evaluating student e-portfolios using an E-portfolio Assessment Management System (EAMS). The EAMS was developed by the University to provide students with an electronic environment to submit, get feedback, reflect and save key learning experiences. The rationale of the EAMS is to allow students to gather, store and present important projects. The students' e-portfolios are also used to demonstrate growth toward achieving specific learning outcomes to measure what students have learned and are able to do when they complete their degree program. Students start using the EAMS in semester three of their degree programs and begin the development of a working e-portfolio by archiving all major projects, their instructors' feedback as well as their reflections.

In this study, we surveyed students from the College of Technological Innovation to learn about their perception and attitude towards using e-portfolios to showcase key learning activities and to foster learning. Three major research questions guided this study: (a) Can e-portfolios facilitate student learning? (b) Can e-portfolios help students better manage their learning outcomes? and (c) Can e-portfolios help students become independent learners? A total of 165 students from the CTI College were randomly selected to take the questionnaire and 132 students (80 percent) agreed to participate and returned filled out questionnaires. The survey was distributed to students taking eight courses at the sophomore and junior year levels.

Study results show that overall; students have a positive attitude and opinion towards having to use the EAMS to store their work and to document the achievement of specific learning outcomes. Students feel that they improved their learning experiences through the use of reflection. They also believe that using their e-portfolios allows them to better manage their learning. However, students did not think that they have

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become more interested in their courses or their degree program as a result of using their e-portfolios. The study also found that about half the students actually enjoyed having to develop and maintain their e-portfolios to show achievement of various learning goals. Finally, as the system encourages the establishment of clear learning goals and expectations, students are taking responsibility to demonstrate that they are achieving their learning goals and faculty are helping students achieve these goals while tracking their progress towards achieving their learning outcomes.

Keywords: Electronic Portfolio, Learning Curriculum, Evaluation, Student Perspectives, Outcome -Based Higher Education

E-Portfolios in Educational Institutions

In recent years, there has been a growing interest in the use of student e-portfolios for assessing the achievements of student learning outcomes (Drost, Hanson, Molstad, Peake, & Newman, 2008). Portfolios have been traditionally used by students in disciplines such as art and architecture as a means of collating evidence of achievements (Harun & Cetinkaya, 2007). During, the last decade there has been a significant increase in the use of student portfolios in other disciplines such as nursing, information technology and engineering (Juwah et al., 2012). So what is an e-Portfolio? And what are the purposes and benefits of using e-portfolios by students?

Paulson et al. (1991) describe a portfolio as a meaningful collection of student work that demonstrates progress and/or mastery guided by standards and includes evidence of student self-reflection. Buzzetto-More (2006) indicates that electronic portfolios provide a unique way to document student progress, encourage improvement and motivate involvement in learning. Buzzetto-More (2006) defines portfolios as an effective form of alternative assessment that encourages students and educators to examine skills that may not be otherwise accessed using traditional means such as higher order thinking, communications, and collaborative abilities. Moreover, e-portfolios provide a framework where students are actively engaged in the learning process and become reflective learners. The benefits of reflective learning are numerous and many studies documented the impact of reflecting learning on people. Examples of these studies include a study by Mezirow (1991) on how adults learn by making meaning of their experiences, and a study by Jordi (2011) on how reflective learning can facilitate the learning process.

Several research studies have addressed the purposes and benefits of e-portfolios to students (Acker, 2012; Kellough & Kellough, 1999; Siemens, 2004). A complete list is outside the scope of this study. Here is a brief summary listing the usefulness and benefits of student e-portfolios:

- E-portfolios are formative in nature and focus on personal development through the use of self-evaluation and reflection
- E-portfolios allow for reflections on artifacts as well as how they match goals and standards
- E-portfolios are tools to communicate with stakeholders (students, faculty, administrators, and employers)
- E-portfolios increase learning effectiveness
- E-portfolios identify students' strengths and weaknesses
- E-portfolios review, assess, and improve the effectiveness of curricular programs
- E-portfolios provide useful administrative data that will expedite decision making
- E-portfolios model professionalism, and enhances information technology skills
- E-portfolios allow for academic credits for learning beyond the classroom

- E-portfolios can be used as an assessment tool where students are required to show how they acquire knowledge and skills through the selection of and reflection on their learning activities
- E-portfolios can be used as a tool to help career centers find jobs for students
- E-portfolios help advisors monitor student learning
- E-portfolios can be used as a tool to meet the requirements from accrediting boards

The above benefits resulted in the relatively quick adoption of e-portfolios by many educational institutions and encouraged these institutions to establish clear learning goals and expectations.

A summary of the literature shows that e-portfolios can be a great resource for both students and faculty as they can facilitate student learning and help students accomplish important learning goals. However, the above studies did not investigate how e-portfolios could be used to help students demonstrate the achievement of learning outcomes in an outcome-based academic setting, which makes this study unique.

Purpose of the Study

This study focuses on the students' attitudes and opinions towards the usefulness of e-portfolios to demonstrate achievement of learning outcomes, getting feedback from their instructors, as well as using e-portfolios as a tool to become active and reflective learners.

Three major research questions guided this study:

(a) Can e-portfolios facilitate student learning and help them achieve their learning goals?

(b) Can e-portfolios help students better manage the learning process?

(c) Can e-portfolios help students improve their learning experiences and become reflective learners?

A survey questionnaire was developed to gather data in order to find an answer to the above questions and also learn about the students' attitudes and opinions about developing and using their e-portfolios to accomplish their learning outcomes.

The Institution under Study

Zayed University (ZU) is an academic public institution in the United Arab Emirates (UAE). It offers an academic program that prepares students for success in education, arts, business, media, and information technology. ZU is an outcome based institution concerned with "learning outcome assessments", how student learning and growth are measured, evaluated, and demonstrated over their years of study. Currently, the University is educating more than 8,500 male and female students from 19 countries in two campuses one in Abu Dhabi and the other in Dubai. The university endeavors to provide students learning opportunities using the American style of education and learning to ensure a quality education. The University has been accredited by the Middle States Commission on Higher Education in 2008. The majority of the faculty members have a terminal degree from North America, Europe, or Australia (Zayed University, 2012).

ZU has an excellent technology infrastructure. Its campuses are fully networked and allow students to connect to various university networks and the Internet from anywhere on campus. All the university has wired and wireless connections (classrooms, library, offices, student hubs, cafeteria, etc). Furthermore, each student is required to purchase a laptop and each faculty member receives a laptop with a three-year replacement schedule.

Students have easy access to technology in order to facilitate the learning process. Actually, ZU is known as the laptop university in this region. In the College of Technological Innovation (CTI), students have their own laptop loaded with the necessary software for their courses. This allows them to complete their work independently, without having to be on campus all the time. The CTI has an independent network infrastructure for teaching and research, in addition to the university's main network. This infrastructure allows students to login remotely into Linux servers to use tools needed for programming languages, databases, and web development courses. Students can also use Linux-based communication tools to collaborate with each other and with their instructors. All ZU courses are implemented on Blackboard Learn$^+$, a learning management system. ZU students can access Blackboard Learn$^+$ from anywhere at any time using a web client service.

ZU has adopted an outcome based learning framework to provide a strong focus to the students' learning outcomes and to improve both curriculum and learning practices. The Academic Program Model (APM) was developed by faculty and emphasizes a commitment to a learner-based education and to shift the teaching paradigm to a student learning model. This model focuses on what students can actually do after they graduate. More details about this model can be found in the ZU internal report on "Self-Assessment Based on Accreditation Standards of the Middle States Commission on Higher Education", and the ZU Academic Program Model (Zayed University, 2012). The purpose of the outcome-based model is to provide students with a focused and coherent academic program and to prepare graduates for a rapidly changing and unpredictable future. It is outcome driven and uses the traditional Grade Point Average (GPA) system. The framework that constitutes the academic program model is composed of three components:

- Readiness program to ensure that students are competent in English language
- General Education
- Degree Major

A major objective of the undergraduate experience at ZU is the development of the skills necessary for continuous lifelong learning. The APM is designed to help achieve this objective by providing students with a foundation and framework for all university studies. Every ZU course focuses on one or more of the six university-specified learning outcomes. The learning outcomes are incorporated into normal course work and, therefore, are an integral part of disciplinary content and evaluation of the course. Threaded throughout the baccalaureate curriculum, the learning outcomes help students achieve a higher order of intellectual development. ZU has six graduation requirements, called Zayed University Learning Outcomes (ZULOs), for all students regardless of their major. These requirements are depicted in Table 1 (Zayed University, 2012):

Table 1: Zayed University Learning Outcomes

Learning Outcome	**Description**
Information Literacy and Communication	ZU graduates will be able to recognize information needs, access and evaluate appropriate information to answer those needs, and communicate effectively to a variety of audiences in both English and Arabic.
Information Technology	ZU graduates will be critically aware of the implications of information technology on the individual and on society and be able to use IT to communicate and solve problems in an ethical way.
Critical Thinking and Quantitative Reasoning	ZU graduates will be able to use information, reasoning, and creative processes to achieve goals and make responsible decisions.

Global Awareness	ZU graduates will be able to relate to communities beyond the local, perceive and react to differences from an informal and reasoned point of view, and be critically aware of the implications and benefits of cultural interaction.
Teamwork and leadership	ZU graduates will be able to work efficiently and effectively in a group. ZU graduates will be able to assume leadership roles and responsibilities in a variety of life situations and accept accountability for the results.
Bilingual	ZU graduates will be able to communicate effectively (oral and written) in both English and Arabic.

Outcome-Based Computing Curriculum

Student learning outcomes have become the focus of many universities as a way to measure and document student learning (Chambers & Wickersham, 2007). Chambers and Wickersham (2007, p. 352) indicated that "these outcomes measure how a student's university experience has supported their development as individuals and describes the knowledge, skills, abilities and attitudes students are able to demonstrate upon completion of a program." Furthermore, the methods by which these learning outcomes are assessed to determine student success of learning expectations vary and may be dependent upon the course, program, and/or assessment practices and beliefs of the faculty**.**

The Information Technology program under study strives to meet the demands of government and industry in the UAE technology market. This cooperative process usually includes advisory boards, called National Advisory Council (NAC), where industry leaders communicate the technical needs to faculty and administrators. Currently, the CTI offers three tracks: Security and Networking, Enterprise Computing, and Multimedia Design. All core courses in each sequence include specific university learning outcomes (ZULOs) and specific major learning outcomes (MALOs) that are applicable to the courses contents. The college programs have been accredited by the Accreditation Board for Engineering and Technology (ABET http://www.abet.org/) in 2010.

The CTI has established six learning outcomes that complement the learning outcomes of the Academic Program Model (see Table 2). These major learning outcomes form the basis for analysis and assessment that play an essential role in the continuous process of improvement.

Table 2: Major Learning Outcomes for the College of Technological Innovation

Learning Outcome	Description
Critical Thinking and Quantitative Reasoning in IT	IT College graduates will be able to use critical thinking and quantitative processes to identify, analyze and solve problems, and evaluate solutions in an IT context.
Information Technology Application	IT College graduates will be able to select existing and cutting-edge IT tools and procedures to develop modules and systems.
Information Technology Management	IT College graduates will be able to assess and determine information resource requirements to develop solutions suitable for IT and business managers operating in a multinational and multi-cultural environment.

Information Technology Professional Practice	IT College graduates will be able to work effectively in individual and group situations, understand how groups interact, be able to assume a leadership role when required, and understand the fundamentals of professional and ethical conduct.
Information Technology Systems Theory and Practice	IT College graduates will be able to understand and communicate the fundamentals of systems theory in the development of appropriate systems that function in a global environment.
Technical Communication (Bilingual)	IT College graduates will be able to express themselves effectively and efficiently in both English and Arabic while using the correct IT terms for each language.

E-Portfolio Assessment Management System

The e-Portfolio Assessment Management System (EAMS) was developed in 2007 to help faculty assess student learning outcomes and evaluate how courses and College programs are meeting institutional goals. The system is described in detail in a previous journal paper (Tubaishat, Lansari, & Alrawi, 2009). The system is an e-learning system that focuses on knowledge representation and learning by reflection. It is a repository management system that facilitates collecting, sharing, and presenting artifacts of student learning outcomes via a digital medium. The system is introduced to students early in their courses to give them time to learn and understand how to upload, and reflect on their e-portfolio artifacts. All artifacts are carefully selected by the students to showcase their best work. This process allows them to demonstrate what they have actually learned and helps them reflect upon the learning process.

The system was built around two predefined set of learning outcomes:

- An institutionally agreed upon set of student learning outcomes, ZULOs, listed in Table 1.
- Learning outcomes that are related to the major's requirements, MALOs, listed in Table 2.

The EAMS is a web-based e-portfolio management system developed by the university. The rationale of the EAMS is to allow students to collect key courses learning items that represent their accomplishment towards the satisfaction of the learning outcomes using a pedagogical web-based environment. The hope is for students to become more focused learners as well as promote responsibility and ownership in the learning process; and ultimately becoming lifelong learners. The drive for the implementation of the EAMS came from two components within our institution: the first is the University's commitment to the proper implementation of the learning outcomes by making sure that they should be included in courses at various levels of achievement (Beginning, Developing, and Accomplished). The second driving force is the ABET accreditation body, which requires the university to showcase evidence of learning achievements against the chosen professional skills criteria.

The purposes of the EAMS can be summarized as follows:

- To show student growth and change over time
- To allow student input into the learning process
- To track the development and course integration of learning outcomes (MALOs, ZULOs)
- To measure how students accomplish their MALOs
- To provide an opportunity for students and faculty members to discuss learning outcomes and the progress toward achieving institutional goals (ZULOs)
- To measure student's performance based on samples of their work
- To help students learn/develop self-evaluation

How Does the EAMS Work?

The EAMS is an important resource used in all Colleges for various assessment activities. The system includes a searchable, electronic storage area where specific examples of student work are uploaded from their courses. Students regardless of their major start using the EAMS in semester three of their degree program and therefore begin the development of a working e-portfolio by archiving projects and other assignments, as well as their instructor's feedback and reflections during early courses.

In each course in the Information Technology concentrations, faculty members are required to include assignments designed to assess one or two of the six MALOs presented in Table 2. Because the e-portfolio assignments are the key component to the success of the learning outcomes assessment process, faculty members are encouraged to design assignments that provide students with an opportunity to demonstrate their most distinguished performance and scholarly accomplishments. Examples of appropriate e-portfolio assignments include a term paper, a project work, a programming assignment, or a network design. Faculty members are required to provide a criteria sheet for each portfolio assignment that explains the purposes and the learning objectives assessed. After reviewing their students' work faculty members comment on the work and post their feedback in a designated area of the EAMS. Moreover, faculty members evaluate both the assignment's general effectiveness and its level of accomplishment with respect to the desired outcome(s). Students are then able to access the faculty comments from the EAMS, as well as any other work posted on the system. This process enables students to update their work and reflect on their learning experience.

The EAMS was designed to function as an archive for research on the effectiveness of various courses in achieving learning outcomes. Because all major student work is uploaded to the EAMS system, research into student achievement of learning outcomes in specific courses or sequences of courses can be easily carried out. Furthermore, all student work can be sorted and studied either by course or by learning outcome. The CTI has accumulated a significant amount of data from the EAMS to evaluate students' achievements towards the accomplishment of their chosen learning outcomes.

Figure 1 shows the EAMS interface. The interface shows, for a particular faculty member, the courses being taught as well as the assessment criteria posted by the instructor. It allows him/her to select the term code and the courses in that semester through accessing e-portfolio systems via the Intranet or extranet.

After matching courses with learning outcomes, faculty members develop key assignments for the courses to optimize their learning target. The assignments may include a major term paper, a lab exercise, a design for building a network, or a case study. Figure 2 shows another snapshot of the EAMS for an e-portfolio course (CIT490) with committee member names, learning outcomes, and assessment criteria used in this course. After grading the piece of evidence, the instructor posts the assessment feedback. The students can then access the instructor's feedback and modify their work as needed. Finally, the students have the option to include that piece of evidence as an artifact in their e-portfolio.

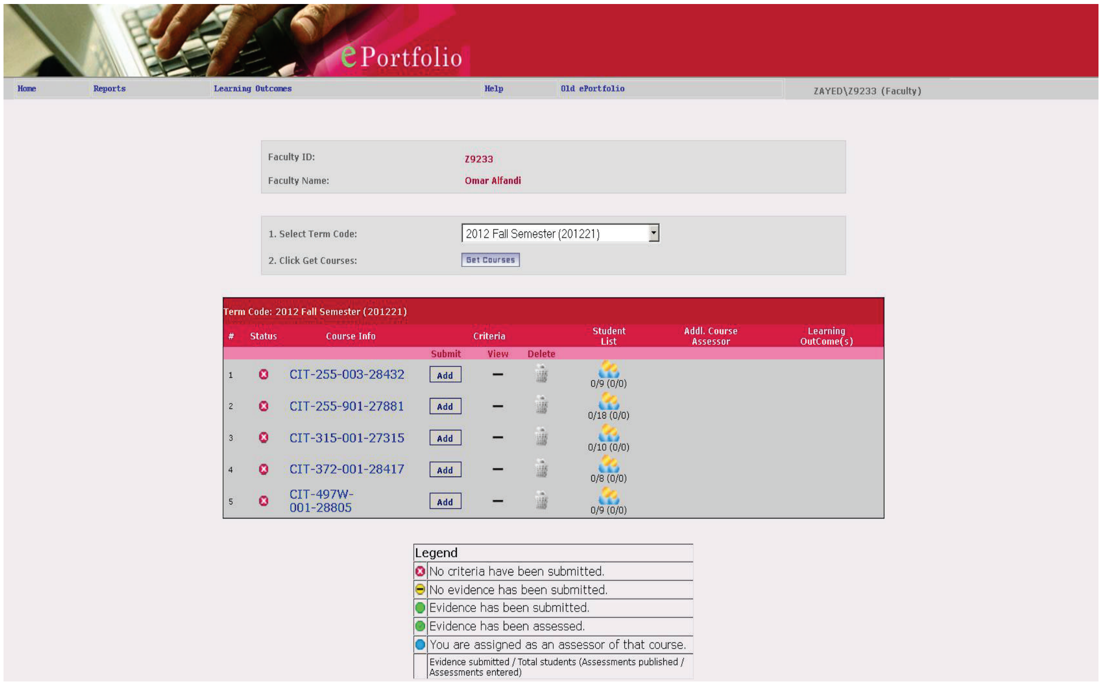

Figure 1: E-portfolio Assessment Management System Interface

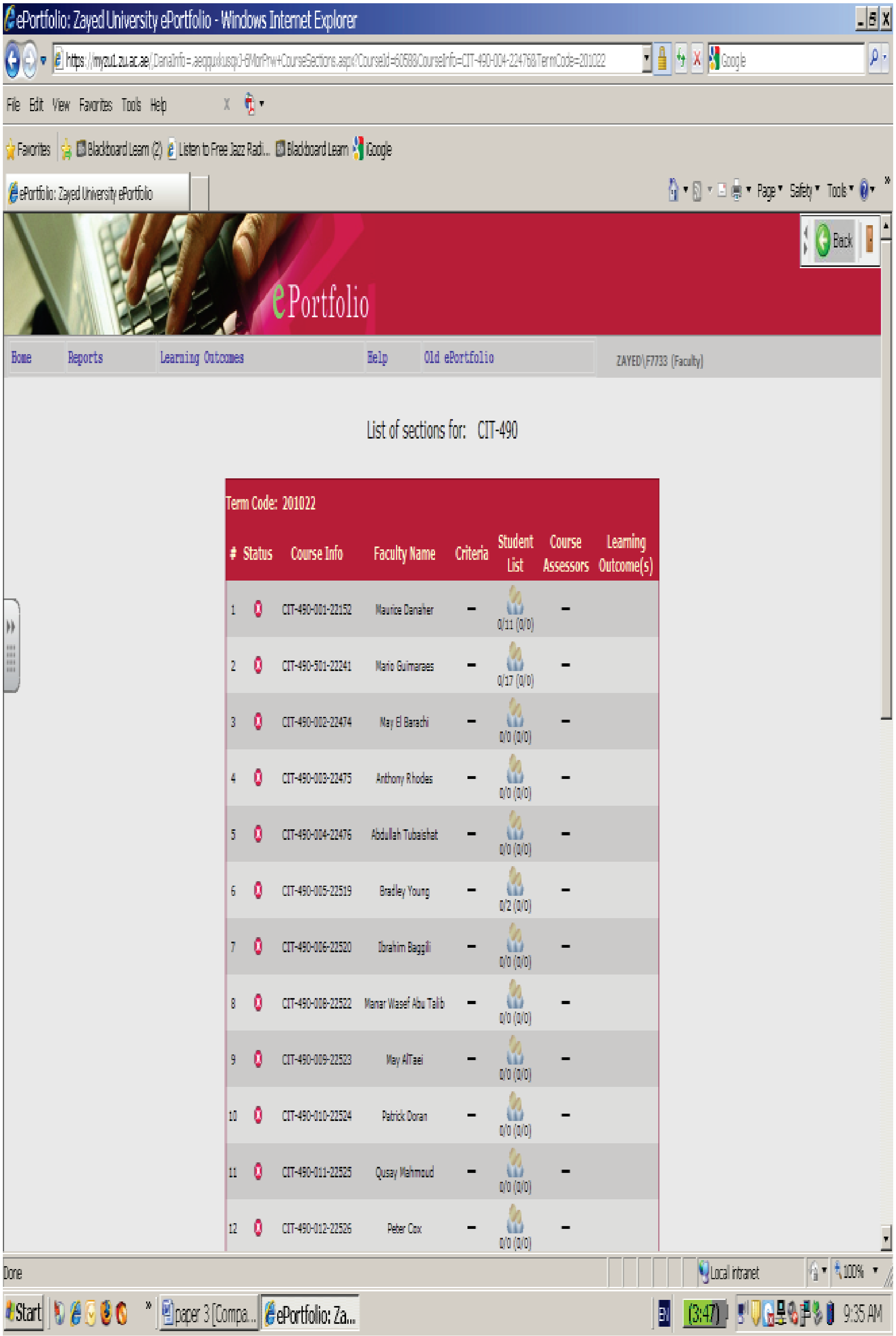

Figure 2: E-Portfolio Course Information, Committee Members, Learning Outcomes and Assessment Criteria

Case Study

Objective of the Study

The purpose of this study is to investigate the effectiveness of using e-portfolios to help Information Technology students in the CTI College select, reflect and organize key learning experiences to demonstrate the achievement of their learning outcomes. The study also investigates the student's impression on the usefulness of e-portfolios as a tool to help them plan and achieve their courses and learning goals.

Study Participants

A total of 165 students from the College of Technological Innovation (formerly College of Information Technology), which uses an outcome-based academic curriculum, were randomly selected for taking part in a survey study. The total number of students selected for this study included 127 females and 38 males. However, only 132 students (about 80 percent of the selected students) agreed to participate in the study and filled out the questionnaire on time. The survey questionnaire was distributed to students participating in the following courses: CIT210 (Introduction to IT and Systems, CIT215 Computing Foundations, CIT245 (Web Development), CIT255 (Network and Telecommunication), CIT320 (Programming and Problem Solving), CIT335 (Information Security Technologies), CIT360 (Management of Information Systems), and CIT372 (Cloud Computing). The variety in course selection was based on the idea that courses should cover a variety of topics and be from different levels of study in this case from the sophomore and junior years.

Questionnaire Data Collection and Analysis

A structured one page questionnaire was designed to survey and collect data from sophomore and junior students, both male and female. The survey questionnaire consisted of seven Likert scale response questions. The questionnaire was made up of twelve closed-ended questions with five multiple choices (Strongly Disagree, Disagree, Undecided, Agree, Strongly Agree). Students completed the questionnaire during the Spring semester of 2012. Prior to distributing the questionnaire, ethical approval to conduct the study was obtained from the university. Below are the survey statistics and data analysis of the survey results. Table 3 shows all the questions with the analysis of data.

Table 3: Survey Questions and Statistics

Category / Questions	**Answer**				
Learning Domain	**SD**	**D**	**U**	**A**	**SA**
My e-portfolio helps me improve my learning experiences	4.8	10.3	24.7	44.2	16
My e-portfolio helps me decide what I need to do to achieve my learning goals	1.8	14.5	27.3	43.9	12.5
My e-portfolio has made me more interested in my degree program	4.2	13.3	33.3	33.4	15.8
My e-portfolio makes me more interested in courses	2.4	20	37.6	33.3	6.7
My e-portfolio helps me decide which courses to take to achieve my learning goals	4.2	17.6	36.4	32.7	9.1

My e-portfolio has been fun to put together	1.8	12.7	30.3	41.2	14
My e-portfolio allows me to get better feedback on my work	3.6	5.5	15.6	50.9	24.4
My e-portfolio helps me to reflect on my work	4.8	3.6	15.2	49.8	26.6
My e-portfolio helps me monitor my progress towards achieving goals in my degree program	2.4	7.9	24.8	50.1	14.8
My e-Portfolio helps me use feedback from my teachers to improve my work	2.4	11.5	17.6	41.2	27.3
My e-Portfolio helps me become better organized in my work	2.4	7.9	19.3	48	22.4
My e-Portfolio has helped me plan and improve my learning experiences	1.8	13.9	20.6	45.9	17.8

Student Response and Data Analysis

A survey questionnaire was developed to gather data to try to find an answer to the above questions and also learn about the student's attitudes and opinions about developing and using e-portfolios: Twelve questions were developed to gather the data needed to answer the research questions. Table 4 shows all the questions with the respective students' responses and analysis.

Table 4: Questionnaire Response Analysis
1. **My e-portfolio helps me improve my learning experiences**: The first question in the questionnaire was designed to learn about the overall students' perception on the use of an e-portfolio toward improving their learning experience. More than half the students either agreed or strongly agreed that the use of e-portfolios have helped them improve their learning. About 15 percent either disagreed or strongly disagreed with the statement that their e-portfolios have helped them improve their learning. A quarter of the students were unsure whether e-portfolios helped them or not.
2. **My e-portfolio helps me decide what I need to do to achieve my learning goals**: The second question was designed to learn whether using e-portfolios has helped students make decisions to reach or achieve their learning goals. More than half the students either agreed or strongly agreed (56 percent). About a quarter of the students (27 percent) was undecided as to whether e-portfolios helped them achieve their learning goals and 16 percent either disagreed or strongly disagreed that using e-portfolios helped them achieve their learning goals.
3. **My e-portfolio has made me more interested in my degree program:** The third question was designed to learn whether through the use of e-portfolios students became more interested in their degree program. Less than half (49 percent) strongly agreed or agreed with that statement. One third (33 percent) were undecided and about 18 percent either disagreed or strongly disagreed that using e-portfolios made them more interested in their degree program.
4. **My e-portfolio makes me more interested in courses:** The fourth question was designed to learn about the relationship between the use of e-portfolios and the students' interest in the courses they took. Only 6.7 percent seemed to strongly agree and 33 percent responded with agree to that question. About 38 percent were undecided and a little less than a quarter (22 percent) either disagreed or strongly disagreed with the statement that their e-portfolios made them more interested in their courses.

5. **My e-portfolio helps me decide which courses to take to achieve my learning goals:** The fifth question was designed to learn whether using e-portfolios helped students decide which courses they need to take to achieve their learning goals. Only 42 percent agreed or strongly agreed to that statement. More than one third of the students (36 percent) were undecided and 22 percent either disagreed or strongly disagreed with that statement.
6. **My e-portfolio has been fun to put together:** The sixth question was designed to learn about the student's attitude and willingness towards building and using the e-portfolio. More than half the students (55 percent) either agreed or strongly agreed. About a third (30 percent) were unsure about that statement and about 15 percent either disagreed or strongly disagreed to having fun while developing their e-portfolios.
7. **My e-portfolio allows me to get better feedback on my work:** The seventh question was designed to learn about the student's opinion on whether they received better instructor feedback using their e-portfolio. More than 75 percent of the students either strongly agreed or agreed that the use of e-portfolios helps them get better feedback from the instructors. Around 16 percent of the students were undecided about that perception and only 9 percent disagreed or strongly disagreed about the fact that e-portfolios allow get to get better feedback from their instructors.
8. **My e-portfolio helps me to reflect on my work:** The eighth question was designed to learn about the possibility that e-portfolios can help students in their reflections after receiving the instructor's feedback on their posted work. More than 76 percent of the students responded by either agree or strongly agree to the fact that the use of their e-portfolio helped them in reflecting on their work. About 15 percent were undecided and 9 percent either disagreed or strongly disagreed that using their e-portfolios helped them reflect on their work
9. **My e-portfolio helps me monitor my progress towards achieving goals in my degree program:** The ninth question was designed to learn about the student's impression from the use of the e-portfolio to help them monitor their progress towards achieving their learning goals in their degree program. About 65 percent of the students either agreed or strongly agreed to that statement, 25 percent were undecided whether their e-portfolio helped them monitor their progress towards achieve their goals. Around ten percent disagreed or strongly disagree to that statement.
10. **My e-Portfolio helps me use feedback from my teachers to improve my work:** The tenth question was designed to learn about the possibility that the e-portfolio platform helped students receive instructor feedback to plan and/or improve their learning experiences. These experiences usually are the student's key pieces of evidence towards achieving learning outcomes. About 69 percents agreed or strongly agreed to that statement, about 18 percent were unsure or undecided and about 14 percent either disagreed or strongly disagree to the fact that their e-portfolios could help towards that goal.
11. **My e-Portfolio helps me become better organized in my work:** The eleventh question was designed to learn whether the use of e-portfolios can facilitate the process of selecting and organizing the students' most significant work. About 70 percent of the students responded positively by choosing agree or strongly agree. Around 19 percent were undecided and 10 percent chose either disagree or strongly disagree as their choice of answer.
12. **My e-Portfolio has helped me plan and improve my learning experiences:** The twelfth question of the questionnaire was designed to learn about the overall usefulness of the e-portfolio as a planning tool to optimize students learning experiences. Almost 64 percent of the students responses to the question were either agree or strongly agree. Almost 21 percent of the students were undecided and almost 16 percent chose either disagree or strongly disagree that their e-portfolios help them plan and improve their learning experiences.

Data Analysis Summary

The analysis of the survey data shows that more than half the students (Q1: 60 %, Q12: 64 %) believe (agree or strongly agree) that using e-portfolios helped them improve their learning experiences. Students also agreed with the fact that their e-portfolios help them get feedback from their instructors thus helping them improve their work (Q10: 69 %), they help them reflect on their work (Q8: 76 %), and students believe that e-portfolios help them monitor progress towards achieving their learning goals (Q9: 65 %). Therefore the answer to the first two questions of this study "can e-portfolios facilitate student learning and help them achieve their learning goals" and "can e-portfolios help students better manage the learning process" the answer is positive.

On the other hand, only half the students think that using e-portfolios have actually helped them become more interested in their degree program (Q3: 49%) or their courses for that matter (Q4: 40%). Furthermore e-portfolios did not seem to significantly help students decide which courses to take to achieve their learning goals (Q5: 42 percent). Therefore the answer to the third question of this study "can e-portfolios help students improve their learning experiences and be reflective learners" is still unclear. Finally, as to whether students had fun putting together their e-portfolios about half of the students agreed to that statement (Q6: 55 %) and about a third were undecided (30 %).

Conclusions

An outcome-based university in the gulf region uses an academic program built around two sets of learning outcomes: an institutionally agreed upon set and a College specific set. Furthermore, the university has recently developed an e-portfolio assessment management system (EAMS) to allow Colleges to document and assess important student work, provide them with feedback on their work, and track the students' learning outcomes achievements. The system is an electronic repository management system that facilitates collecting, sharing, and presenting students work. Students are encouraged to use their e-portfolios to gather and analyze their most significant work.

In this study, 165 students were randomly selected for the distribution of a research questionnaire to learn about the students opinions on the usefulness of their e-portfolios as a tool to enhance their learning experiences. About 80 percent of the selected students (132) agreed to take part in this study and filled out the questionnaire. The survey was distributed to students in eight courses across the sophomore and junior years of the CTI academic program. Analysis of the questionnaire responses showed that the majority of the students value their e-portfolios and believe that using their e-portfolios actually helps them achieve their learning objectives. They also believe that their e-portfolios (via the EAMS) allow them to receive the instructor's feedback quickly. This allows them to improve their work and monitor their progress toward achieving their learning goals.

Students however, did not seem to think that the use of e-portfolios made them more interested in their courses and degree program. Moreover, the use of e-portfolios did not help them decide which courses they needed to take to achieve their learning goals. Therefore, the faculty advisor has still an important role in that respect. Finally, only about half the students seemed to actually enjoy developing and using their e-portfolios. This may be due to the fact that some students feel they spend too much time in the process of keeping up and updating their e-portfolios.

The use of outcome-based curricula and students' e-portfolios to foster learning is still at an early stage in the UAE and the Gulf region. In the CTI College both students and instructors are learning how to best use e-portfolios to achieve key learning goals. The next step in this research is to learn whether the use of the E-portfolio Assessment Management System will help move *both* instructors and students towards a better teacher/learner relationship where the instructor's guidance is more effective.

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Biographies

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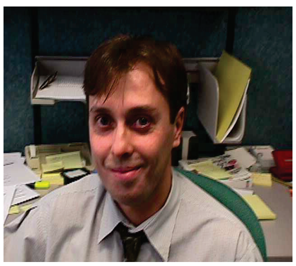

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Student Engagement with Online Resources and Its Impact on Learning Outcomes

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Executive Summary

There is an increasing demand and expectation for universities to incorporate greater levels of technology into the design and delivery of their curriculum. From an academic perspective, it is of significant interest to determine whether the increased use and availability of online teaching resources have made a positive impact on students' academic performance and whether this is reflected in improved learning outcomes. This paper reports on the findings from a survey of first-year accounting students to assess the level of student engagement with online learning resources. The results indicate that, despite having three new online options readily available via WebCT, students expressed strong support for the traditional face-to-face approaches delivery as the more effective learning options. To determine whether the access to additional online resources had any impact in assisting the students' learning in this subject and potentially affecting their assessment outcomes, a review was conducted to compare the overall pass rates attained. It was found that the period in which the improvement was most significant coincided with the availability of online recordings lectures and tutorials. An investigation of WebCT Course Management Statistical Tools revealed a positive relationship between the level of student engagement with online resources and their overall academic result. Across the key online activities measured, the time spent on each activity was considerably longer for the High Distinction students in comparison to failed students. The analysis of the results has been beneficial in identifying the online learning resources that are most useful in supporting student learning and provide guidance for further enhancement to the design and delivery of e-learning content in this subject.

Keywords: student engagement, online resources, technology, learning outcomes, e-learning

Introduction

The continual emergence of new technologies has placed academic staff under increasing pressure to react to these substantial changes within a very short and often unrealistic time-frame. As stated by Bates and Poole (2003, p.xiii), one of the major challenges of teaching with technology is that "you cannot possibly keep up with the technology. The paradox of technology enhanced education is that technology changes very rapidly and human beings change very slowly." This paper is written from the viewpoint of the coordinator of an introductory accounting subject. The students enrolled in this compulsory first-year accounting subject are a very diverse group comprising accounting and non-accounting students from a broad spectrum of business degrees which range from music through to marketing. It is important that the curriculum material is developed with an understanding of the differences among these students. Due to the considerable amount of time and effort invested in the design, development and implementation of suitable online resources to support student learning in this subject, validation of its educational value is sought.

Literature Review

Students in their first year of university have distinct learning needs arising from the social and academic transition they are experiencing. From multiple starting points, all students are on a journey to becoming self-managing and self-directed learners and the first-year curriculum should help get them there (Nelson, Kift, Humphreys & Harper, 2006). The introduction of e-learning and online resources enables a greater degree of flexibility in providing support for the diverse demands of these students. Ginns and Ellis (2007) acknowledged the increasing pressure for greater integration of new technology into the student learning experience. Wells, de Lange and Fieger (2008) found that the use of technology in educational settings assists in the achievement of learning outcomes. Buzzetto-More (2008) and Sanders & Morrison-Shetlar (2002) report that student attitudes toward technology are influential in determining the educational benefits of online learning resources and experiences. Research conducted by Perera and Richardson (2010) suggests that the quality of the actual time spent online may be influential on learning outcomes. This provided some support for an earlier study by Davies and Graff (2005) which found that students interacting less frequently with online resources performed less well academically. A more recent study by Williams, Birch, and Hancock (2012) explored the relationship between levels of student engagement with online quizzes and their academic performance. The study found that students who attempted the online quizzes multiple times performed much better than those who attempted a fewer number of times. Osgerby (2013) investigated students' perception of the introduction of a blended learning environment. It was concluded that whilst students appeared to have a positive attitude to the adoption of an organised and well-resourced ICT based learning process, they preferred lectures and step-by-step instruction. Research conducted by Naaj, Nachouki, and Ankit (2012) considered student satisfaction an important factor in measuring the quality of blended learning. Their study proposes that students' satisfaction is influenced by a combination of factors which include the instructor, the technology, class management, interaction, and instruction.

Ginns and Ellis (2007) identify that extensive research into quality student learning in higher education has been conducted by prominent researchers in the field which include Biggs (2003), Entwistle and Ramsden (1983) and Prosser and Trigwell (1999). Outcomes from their research have helped to identify key concepts related to quality learning in higher education and are shown in Figure 1.

Represented in this diagram are the key concepts arising from this research as they relate to the quality of learning achieved by students. This paper will focus on Concept 2, which relates to students' perceptions of the teaching and learning environment. It will investigate students' attitudes towards the traditional face-to-face methods of teaching in comparison to more recent online learning options. The level of student engagement with these online resources and its impact on student learning outcomes will also be discussed. In a recent literature review, Apostolou, Hassell, Rebele, and Watson (2011) highlighted the need for more empirical studies into the effectiveness of using technology in accounting education. The findings of this paper aim to make a positive contribution to this area of research.

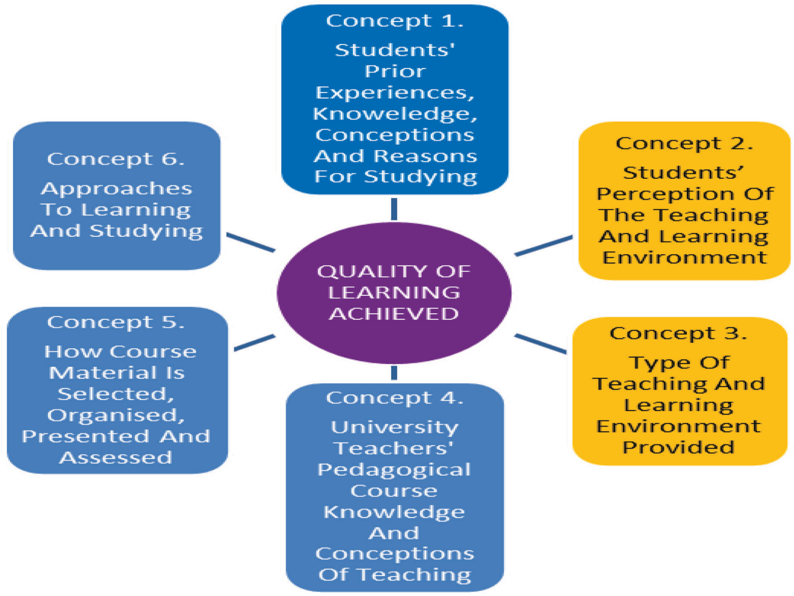


Figure 1 - Concepts Related To The Quality Of Learning At University
Adapted from Entwistle, McCune, & Hounsell (2002, p.6)

Methodology

To assess the level of student engagement with online learning resources and the impact of these resources on learning outcomes, a quantitative approach was adopted for this research. The primary source of statistical data used in this paper has been extracted from a survey specifically designed to identify students' attitudes towards e-learning in the first-year accounting subject offered by Victoria University.

Background on the Study University

Victoria University, located in Melbourne, Australia, has one of the most culturally and linguistically diverse student populations within the state of Victoria. There are a large number of first-generation university entrants, the first in their family to attend university. Also included amongst the student population are those from a low socio-economic background. It is therefore important to provide additional support for their specific learning needs. One of Victoria University's key strategies is to enhance the quality of the learning experience by incorporating a greater use of technology in the teaching and learning process; this trend toward blended learning is emerging as perhaps the most prominent method of delivery in higher education (Bonk & Graham, 2006). Since 2006 there has been an increasing amount of online resources used in Victoria University's introductory accounting subject. A review of the overall pass rate before and after these technological enhancements will be used to determine its impact on learning outcomes.

WebCT, an online learning platform provided by the Blackboard Learning System, was introduced into the first-year accounting subject in Semester 1/2006. Students were provided with a basic level of online teaching resources which included lecture notes and exam solutions. In each of the following semesters, additional resources were made available. These now include instructional videos, online assessment, access to recorded lectures and tutorials, as well as participation in an online tutorial. There is also greater use of communication tools, in particular online chat and discussion boards for students to communicate with each other and their lecturers via WebCT. Students' perceptions of the effectiveness of the online resources and the level of engagement with them will also be discussed.

The Survey

The survey instrument comprised three sections. The first section provided a profile of the socio-economic and educational background of the sample. The second section rated the students' study preferences toward the traditional face-to-face lectures and tutorials, as well as new online teaching options. Each of the options were listed and students were asked to rate their effectiveness of each in assisting their learning in this subject by using a 4 point rating scale. The quality and usefulness of the key features on the subject's website was also evaluated in the same manner. This section also included three open-ended questions seeking students' recommendations on what additional online resources should be incorporated into this subject's website to further help with their learning. The third section provided an overview of the students' learning experience in this subject. Students were asked to respond to a series of statements relating to quality of teaching, assessment, workload and their attitudes toward study by using a 5 point Likert scale.

The length of the survey was limited to three pages and required approximately 10 to 15 minutes to complete to encourage greater student participation. Informal feedback sourced from student emails received during the relevant semesters under review was considered in the analysis of student responses.

The survey was distributed to students in the last lecture at the end of each semester and student participation was voluntary. Survey data was collated and entered into IBM SPSS Statistics 20 software for statistical analysis. Additional sources of information were retrieved from the university's student database, the Victoria University Student Information System (VUSIS), and analytical tools were available on the WebCT course management system for statistical tracking of the usage of the online resources. Academic performance measures and learning outcomes were calculated from comprehensive records kept on Microsoft Excel spreadsheets detailing each component student assessment.

This is a longitudinal study conducted over four consecutive semesters commencing from Semester 1/2010 through to Semester 2/2011. The aim of this research was to identify students' attitudes toward traditional and online methods of delivery and to determine whether the level of student engagement with online teaching resources had made a positive impact on their academic performance in this first-year accounting subject.

Demographic Profile

Table 1 provides a demographic profile of the students surveyed over the four semesters under review from Semester 1/2010 through to Semester 2/2011.

Sample Size

The largest sample size of 172 students was attained in first semester of the survey period but this decreased steadily with only 87 students responding to the survey in the fourth semester .This is reflective of the lower number of students enrolled for this period and lower attendance in lectures. It is possible that this trend may be related to the introduction of recorded lectures and tutorials becoming available online from Semester 1/2010 onwards.

Gender

In semesters 1/2010 and 1/2011 males students represented a slightly higher proportion than female students. This reversed in Semester 2/2010 and 2/2011 with female students more dominant in the sample.

Table 1 - Demographic Profile of Survey Participants

	Sem. 1/2010	Sem. 2/2010	Sem. 1/2011	Sem. 2/2011
Number of Students Enrolled at End of Semester	561	495	468	424
Sample Size	172	112	143	87
Gender	%	%	%	%
Male	56	37	53	47
Female	44	63	47	53
Mode of Study	%	%	%	%
Full-Time	88	88	87	87
Part-Time	12	12	13	13
Which year of study are you in?	%	%	%	%
1st	64	67	67	70
other	36	33	33	30
Are your major studies in Accounting?	%	%	%	%
Yes	35	8	19	15
No	65	92	81	85
Work and Study	%	%	%	%
Not working	27	25	31	31
1-10 hours of work	16	9	11	14
11-20 hours of work	30	44	31	30
21-30 hours of work	15	12	16	14
Greater than 30 hours	12	10	11	11
Age	%	%	%	%
Less than 20 years	44	36	39	36
20 – 29 years	47	58	49	52
30 years or older	9	6	12	12
Studied Accounting Previously	%	%	%	%
Yes	39	22	37	23
No	61	78	63	77
Work Experience in Accounting	%	%	%	%
Yes	13	5	10	5
No	87	95	90	95
How many lectures did you attend?	%	%	%	%
None	1	2	1	1
some	49	50	60	58
All 24 lectures	50	28	39	41
How many tutorials did you attend?	%	%	%	%
None	0	0	0	0
some	41	52	48	52
All 12 tutorials	59	48	52	48

Mode of Study

The vast majority of students (87% to 88%) were studying in full-time mode. These figures remained consistent over the 4 semesters under review.

Year of Study / Previous Accounting Studies / Work Experience

For a large proportion of these students, this subject is undertaken as their first semester in the first year of study at this university. In Semester 1/2010 this accounted for 67% of survey participants; by Semester 2/2011 this had increased to 70%, the highest proportion of first year students over the survey period. A significant majority of students ranging from 61% to 78% have no previous accounting studies. The percentage of students with work experience in accounting was very low representing from 5% to 13% of this sample. These results may be due to the low proportion of accounting majors in this sample.

Major Area of Study

A minority of students enrolled in this compulsory accounting subject are accounting majors. In Semester 1/2010, this amounted to 35% and in Semester 2/2010 this was at its lowest with only 8% of students identified as accounting majors. This is one of the major challenges in engaging these students in the learning of accounting as it is an area of study in which there is little or no interest. The survey results show a larger percentage of students from a non-accounting background in the second semester of each year as accounting majors generally complete this subject in the first semester to be eligible for sequential accounting subjects.

Work and Study

A significant majority of students are working and studying. Of this group of students, the percentage of students that were working between 11 to 30 hours of work each week ranged from 44% to 56%. It was also found that up to 12% of these students worked more than 30 hours per week. This is perhaps reflective of the generally low to medium socio-economic status of the university's student demographic in which students are required to work long hours to cover their educational and living expenses. More flexible learning options may be beneficial to this group to enable them to continue with their studies despite substantial work commitments. The proportion of students that are not working and able to more fully focus on their studies ranged from 25% to 31%.

Age

The dominant groups are those students less than 20 and those between 20 to 29 years old. These two younger groups combined represent approximately 88% to 94% of surveyed students in comparison to mature students aged 30 years or older who account for only 6% to 12% of this group.

Lectures and Tutorials Attended

The percentage of students who attended all lectures was quite low with an attendance rate of 50% recorded in Semester 1/2010. This declined over the three consecutive semesters, with the lowest attendance rate of 28% recorded in Semester 2/2010. It is also noted that 1% to 2% of students did not attend any lectures during the semester.

A similar trend is seen in the percentage of students attending all tutorials with a slightly higher attendance rate of 59% recorded in Semester 1/2010. This also dropped in the following semesters with the lowest attendance rate of 48% recorded in Semester 2/2010 and Semester 2/2011. In contrast to lecture attendance, there were no students in this survey who did not attend any tutorials. This is probably due to students having to complete a mid-semester test. As this is a compulsory assessment for the subject, each student attended at least one tutorial.

Results

In Semester 1/2010, students were introduced to three new online learning options to complement traditional face-to-face lectures and tutorials. These included the viewing of recorded lectures via Lectopia, an automated lecture recording and web publishing tool. Students were also given the opportunity to enroll and participate in online tutorials via Elluminate Live which is an online collaborative session. To join the online tutorial they were required to login to the Elluminate Live website each week at a regular designated time. These sessions were conducted by the subject coordinator. The transfer of knowledge and review of tutorial content was facilitated through shared files or a shared whiteboard which students could also take control of screen for direct input. Interaction between the online tutor and students was enabled through an onscreen dialogue sidebar or speaking directly via microphone or headset. The Elluminate Live tutorials were recorded and access to all these additional online resources was through WebCT.

A screen capture of an Elluminate Live session highlighting these particular features is provided in Figure 2.

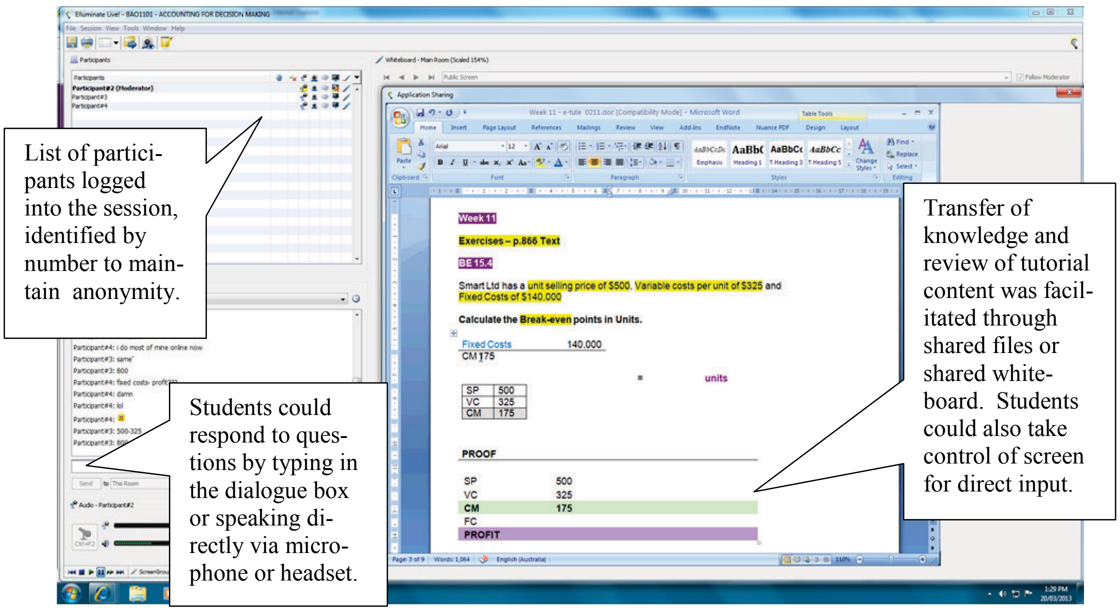


Figure 2 – Screen Capture of Elluminate Live Session

Students' Perceptions of Effectiveness of Learning Options

To gauge how students perceived the effectiveness of each of these options, a 4 point rating scale was used with 1 = not at all effective, 2 = some effect, 3 = effective and 4= very effective.

The mean scores calculated for each of these options are shown in Table 2.

Table 2 - How Effective Was Each Of These Options In Assisting Your Learning In This Subject?

	Semester 1/2010	Semester 2/2010	Semester 1/2011	Semester 2/2011
Lectures - face-to-face	3.42	3.19	3.39	3.64
Lectopia - recorded lectures	2.75	2.84	2.92	3.05
Tutorials - face-to-face	3.33	3.07	3.20	3.33
Elluminate - viewing recorded tutorials	2.51	2.25	2.63	2.54
Elluminate Live - participating in online tutorials	2.46	2.51	2.68	2.34

A graphical representation of the mean scores for each learning option is shown in Figure 3.

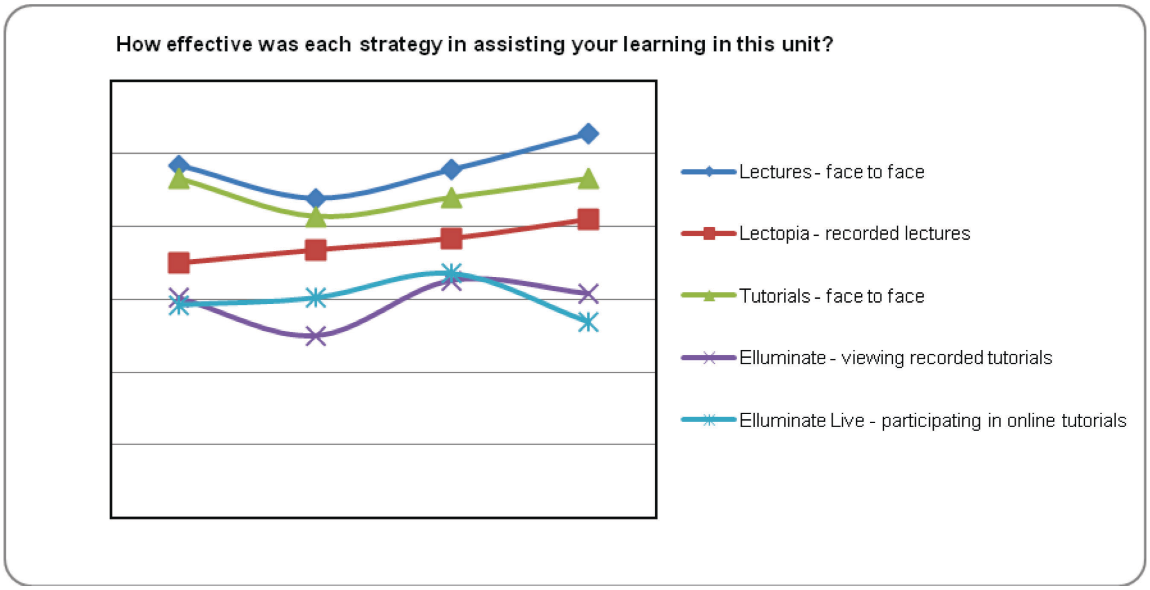


Figure 3 – Effectiveness of Each Option in Assisting Learning

Despite having three new online options readily available via WebCT (the viewing of recorded lectures, the viewing of recorded tutorials, and participation in an online tutorial), there was strong support for traditional face-to-face delivery. There was an initial decline in the mean scores in Semester 2/2010 for face-to-face lectures and tutorials, but from this point onwards, an upward trend continued for both approaches through to Semester 2/2011. The results indicated that the students perceived face-to-face lectures as the most effective option in assisting their learning in this subject with a mean of 3.64 which peaked in Semester 2/2011. A similar trend was evident for face-to-face tutorials with a slightly lower mean of 3.33 for the same period.

Of the online options, the viewing of recorded lectures rated was rated the most highly. Even though it was the only option in which the mean score showed a continual increase from 2.75 in Semester 1/2010 to 3.05 in Semester 2/2011, it rated well below the face-to-face options.

These results appear to be consistent with research by Halabi, Tuovinen, and Farley (2005) on student attitudes toward tele-teaching and traditional face-to-face contact. Preference for face-to-face teaching was reported in this study and more recently in Osgerby (2013) who concluded that whilst students appeared to have a positive attitude to the adoption of organised and well-resourced ICT-based learning options, they still preferred traditional lectures and step-by-step instruction. Over the four semesters, the viewing of recorded tutorials and participation in online tutorials rated the lowest of all the learning options. With mean scores ranging from 2.25 to 2.63 and 2.34 to 2.68 respectively, students perceived these two options to have only some effect in assisting their learning. These low scores are perhaps indicative of their preference for active involvement through student interaction rather than passive viewing of online recordings. Bates and Poole (2003, p. 98) state that "most theories of learning suggest that for learning to be efficient, it needs to be active … the learner must respond in some way to the learning material." Students learn better when they are actively engaged with their learning rather than being passive receptacles of information.

Despite the constant promotion of the online tutorial as a new and flexible learning option over the four semester period, the enrolments remained low with the numbers ranging between 5 to 10 students per tutorial. The number of participants would fluctuate from week to week so the actual number of students online was at times below this stated range. This may be perceived to be a benefit to those who did participate as it provided a more personalised learning experience compared to a traditional classroom tutorial of 25 students. As an instructor, one is able to better gauge the level of understanding of each individual student through the one-to-one interaction online in which student anonymity is maintained. This seemed to encourage more open discussion amongst participants and provide a more active and collaborative learning experience, particularly for those students who feel uncomfortable asking questions in a large tutorial group. It was interesting to note that in Semester 2/2011, the mean score for the participation in the online tutorials was at its lowest at 2.34, whilst the viewing of the recorded tutorials rated slightly higher at 2.54.

The overall decline in the mean scores for face-to-face lectures, face-to-face tutorials and viewing online tutorials for Semester 2/2010 may be attributed to the student profile for this period. With reference to demographic details in Table 1, it can be seen that 92% of this particular group are non-accounting majors of which 78% have no prior studies in accounting, the largest proportion in these categories across the 4 semesters surveyed. It also shows that 44% of these students were working between 11 to 20 hours, which is substantially higher than the 30% and 31% recorded in the other semesters from 1/2010 to 2/2011. This may have contributed to the lower attendance rates for Semester 2/2010 which show that only 28% of these students attended all lectures and 48% attended all tutorials, the lowest over the four semesters reviewed. This may have also influenced the increase in the effectiveness of the Lectopia recorded lectures and Elluminate recorded tutorials to make up for missed classes during this semester.

Students' support for participation in online tutorials as an effective strategy to enhance their learning rose slightly from Semester 1/2010 to Semester 1/2011. The mean score increased marginally over the three consecutive semesters from 2.46 to 2.68, but dipped to its lowest point of 2.34 in Semester 2/2011. Despite numerous attempts by the subject coordinator to raise student awareness of these online tutorials during this semester, this did not seem to improve the low number of enrolments nor strengthen their perception that this was a viable alternative to face-to-face learning.

Student Feedback on Online Learning

As this is the largest accounting subject offered at the university, the teaching is shared between several teaching staff. Consequently, students may be exposed to a range of learning experiences due to differing interpretations of subject content, as well as divergent teaching styles. This was often confusing for students. In an attempt to provide consistency, the unit coordinator's online recordings of lectures and tutorials were posted on WebCT. The popularity for online recordings is reported in Osgerby (2013), in which several students specify that they would have liked recordings of lectures to be available, only if the lecturers were proficient in their subjects.

Despite the lowest mean score of 2.34 recorded in Semester 2/2011, the informal feedback from students participating in these online tutorials was very positive as a flexible learning option which enhanced their learning. Samples of feedback are provided below.

Feedback from an online participant Sem. 2/2011 - extract from email 27/10/2011
"Just wanted to say again how fantastic it has been being a student of BAO1101 this semester. I personally have found the online element and your teaching style extremely advantageous to my learning and thank you greatly for being such an inspirational teacher. I encourage you to keep trying to offer this subject to other students as it had been extremely helpful to me as a travelling student. Though class numbers and the obvious difficulty of distance affects your belief in this (online) subject i encourage you to keep doing what you're doing and only hope that other students can appreciate as much as i do what you have done for me this semester".

Feedback from a viewer of online recordings Sem.2/2011- extract from email 6/09/2011
First of all thank you for the opportunity to access both the lecture recordings and online tutorial recordings, I have found them of great assistance and your teaching style is easy for me to follow. Although I attend both my tutorial and lecture I find I am able to use the recordings for better understanding of the subject".

Feedback from a viewer of online lectures Semester 2/2010- extract from email 27/08/2010
"I am just writing to say thank you and to mention how much I enjoy listening to your lectures. I have been away due to a surgery I recently had so I have been following along with the subject through the recorded lectures and I find your teaching style not only to be very easy to understand and follow, but you make the subject actually enjoyable to study. I have found it very difficult to find lecturers who not only make the subject easier to understand, but have the enthusiasm to want to make their students get the most out of the subject. You definitely have a great passion for this subject as well as a passion for teaching, which is rare. Thank you again and I look forward to learning more from you throughout the semester".

Impact of Online Lectures and Tutorials on Learning Outcomes

The availability of online recordings of lectures and tutorials and their potential impact on learning outcomes is presented in Table 3 below.

Table 3 - Overall Pass Rate

	Prior to WebCT	With WebCT				WebCT Access To Recorded Lectures And Tutorials			
	2005	2006	2007	2008	2009	Sem. 1/2010	Sem. 2/2010	Sem. 1/2011	Sem. 2/2011
Sample Size*	992	1,090	1,357	1,134	1,289	561	495	468	424
Pass Rate	73%	68%	77%	71%	70%	80%	76%	82%	72%

** Sample Size is based on number of students completing final exam*

Table 3 shows that the improvement was most significant from 2009 to Semester 1/2010 where the overall pass rate increased from 70% to 80% which seems to coincide with the availability of recorded lectures and tutorials via WebCT. It is also acknowledged that there may be other contributing factors influencing these results, some of these are summarised in Table 4 below.

Table 4 – Possible Factors Impacting on Pass Rate

	Semester 1/2010	Semester 2/2010	Semester 1/2011	Semester 2/2011
	%	%	%	%
Pass Rate	80	76	82	72
Non-accounting majors	65	92	81	85
No previous accounting studies	61	78	63	77
Working from 11 to 30 hours per week	45	56	47	44
Attended all lectures	50	28	39	41
Attended all tutorials	59	48	52	48

Proportion of Non-Accounting Majors

The decrease in the pass rate from to Semester 1/2010 to Semester 2/2010 from 80% to 76% may be due to the significantly larger proportion of non-accounting majors, 65% compared to 92% in the latter semester, In Semester 1/2011, the highest pass rate over the four semester survey period of 82% was achieved with 81% of non-accounting majors. By Semester 2/2011 the pass rate had dropped substantially from 82% to 72%, marginally below the 73% pass rate recorded prior to the introduction of WebCT. If the Semester 1 results for each semester are compared in isolation, the pass rate has improved from 80% to 82%. This result may be due to the larger proportion of accounting majors enrolled in the first semester of each year. A similar comparison with the Semester 2 results shows a decline in the pass rate from 76% to 72% possibly due to the larger proportion of non-accounting majors enrolled during this period.

Previous Accounting Studies

The high proportion of students with no previous accounting studies was similar for each of the first and second semesters, around 61% and 77% respectively. Coupled with substantially higher proportion of non-accounting majors for the same period, these two factors appear to be the most influential in the overall pass rate.

Hours Worked Per Week

The percentage of students that were working between 11 and 30 hours ranged from 45% to 56% over the four semesters reviewed. This appears to be a considerable workload undertaken given that approximately 88% of the students surveyed over this period were full-time students. This may also have a direct effect on level of attendance in tutorials and lectures during the semester. These students may have found the online recordings a flexible learning option enabling them to continue with their studies and managing their work commitments.

Attendance

There was a downward trend in the level of attendance for all lectures, dropping from 50% in Semester 1/2010 to its lowest point of 28% in the following semester. There was a significant increase in Semester 1/2011 and 2/2011, with lecture attendance rates up to 39% and 41% respectively. The level of attendance for all tutorial was at its highest in Semester 1/2010 at 59% but decreased to its lowest level of 48% in both Semester 2/2010 and 2/2011. The attendance in tutorials is higher for the same period as students have internal assessments which are conducted in the tutorial and require their attendance. Despite the low attendance rates which are mostly below 50% for lectures and tutorials, there is a substantial improvement in the overall pass rate which peaked at 82% in Semester 1/2011. This is considerably higher than the 73% pass rate attained prior to WebCT. It is interesting to note that this was achieved when the proportion of students attending all lectures had declined from 50% to 39% and the proportion of students attending all tutorials was down from 59% to 52%.

Whilst the increased use of web-based technologies such as Lectopia and Elluminate may have some impact on the low attendance rates, Taplin, Low, and Brown (2011) acknowledge research by Phillips, Gosper, McNeill, Woo, Preston, and Green (2007) and von Konsky, Ivins, and Gribble (2009) who argue that other factors contribute to falling attendance rates. These include the changing lifestyles of students as well as their changed perceptions of the learning experience provided.

As can be seen from the data in Table 4, there is the possible interplay of different factors impacting on the overall pass rate. It suggests that where students are working longer hours, where there are a large proportion of non-accounting students with no previous accounting studies and low attendance rates, the overall pass rate may be adversely affected.

Table 5 - Level of Engagement and Learning Outcomes for Semester 2/2011

	Number of Sessions	Total Time Hours Spent	Online Assessments Attempted Maximum =22 times	Average Time On Assess-ments Maximum =5.5 hours	Files Viewed	Discussion Board Messages Read
HD (80-100)						
Frequency / Hours	4,352	1,106	1,002	190	5,056	209
No. of Students	52	52	52	52	52	52
Average*	**84**	**21**	**19**	**4**	**97**	**4**
N2 (0-39)						
Frequency / Hours	3,492	790	1,000	170	6,276	152
No. of Students	134	134	134	134	134	134
Average*	**26**	**6**	**7**	**1**	**47**	**1**

Details accessed from WebCT Course Management Statistical Tools

**Average figures have been rounded up to nearest whole number*

Table 5 shows the level of student engagement with some of the key online resources on WebCT which may assist their learning in this subject. It provides a breakdown of the number of sessions each student logged into, the average time spent on these sessions, the number of online assessments attempted, as well as the average time spent on the online assessments. The frequency of files viewed and the students' participation in discussion board activities is also included to help determine whether the level of interaction with the subject website and learning materials was an influential factor in their overall academic performance.

Two distinct groups of students were compared. The first group being the 'High Distinction' students attaining a final mark between 80 and 100, the latter being the 'N2' students, those who clearly failed the subject with a final mark between 0 and 39.

Sessions Logged

Students are required to logon regularly to the subject website for updates, online assessment, as well as access to important learning materials which include recordings of lectures and tutorials, assignment details, sample tests, past exams, and solutions. On average, High Distinction students logged into 84 sessions and spent approximately 21 hours engaging with the online resources, whereas the failed N2 students logged into 26 sessions and spent approximately 6 hours on WebCT during the semester. This seems to be in contrast with research conducted by Perera and Richardson (2010) which found that the number of online sessions a student logged into was not significantly related to students' academic performance. However, their findings did suggest that the actual time spent online provided some support for an earlier study by Davies and Graff (2005) which found that students interacting less frequently performed less well academically. However, it could be argued that there is likely to be a correlation between the number of hours a student spends online with the number of hours that they spend studying offline.

Online Assessments Attempted

The online assessments comprised eleven tests which were released on a weekly basis to reinforce the students' understanding of the weekly lecture and tutorial content. Students were allowed two attempts for each of these eleven tests, therefore the maximum number of 22 attempts was allowed. The highest score from the two attempts for each of the weekly tests counted toward their final mark. These tests represented 10% of the total assessment in the subject.

The tests comprised theory and practical elements which required some calculations. After completion of each test, students were given immediate feedback on their score and incorrect answers were identified. On average, the High Distinction students attempted the weekly tests 19 times, in comparison to the N2 students who attempted seven times out of the maximum 22 times allowed. These results appear consistent with the findings of Williams et al. (2012) which indicate that students who attempted the online quizzes multiple times performed much better than those who attempted each quiz only once or not at all. Similar results were reported in Osgerby (2013) whereby students regarded online quizzes as very popular where instant feedback is provided. Students also stated that they often repeated the tests as it was helpful to enhancing their background information and building up their confidence.

It was also found that the High Distinction students took a longer time to complete their online assessment, spending approximately four hours out of the 5.5 hours allowed, which is substantially higher than the one hour taken by the N2 students. This may be due to the additional time by the High Distinction group to calculate the answers which could possibly demonstrate a deeper understanding of the technical content than the N2. The lesser time taken by this group may be due to students guessing the answers rather than working through each of the possible options to find the correct answer. Perera and Richardson (2010) propose that it is the quality of time spent within the online environment that has a relationship with students' academic outcomes.

Files Viewed

These files comprise essential learning materials which include lecture notes, tutorial content, assignment details, marking schemes as well as links to websites that are relevant to the subject content and assessment. A similar pattern is evident with the High Distinction students viewing 97 files in contrast to the 47 viewed by the N2 students during the semester. As these files were integral to students' learning, assessment and exam preparation, these results show a potential link between the number of files viewed and improved results. This appears to be consistent with the findings reported by Perera and Richardson (2010).

Discussion Board

The Discussion Board feature is one that is not readily found on the WebCT interface. As it does not appear on the sidebar of the subject's homepage, a number of steps are required to locate it. This may partially explain the very low level of activity from both the High Distinction and N2 students. Despite being shown all the key features of WebCT at the commencement of the semester, it is possible that many students were not aware that this feature existed, or perhaps if they were aware, it was not considered an effective means of communication with this low level of interaction. Similar issues were raised in Concannon, Flynn, and Campbell (2005) who questioned whether technologically-enhanced learning systems were flexible enough to meet the design requirements of an effective learning system. This is reinforced by Osgerby (2013) who comments on the reliability and technical quality of the learning management system, such as WebCT. These factors have been found to have an impact on students' attitudes and willingness to engage with online learning resources.

Details accessed from the WebCT Course Management Statistical Tools for Semester 2/2011 indicated the reading of discussion board messages averaged approximately four messages and one message respectively. There was, however, a greater contrast by comparing the student achieving the highest mark of 96 in this subject reading 21 messages compared to the student with the lowest mark of eight who did not read any messages over the 12 week semester. This student's poor performance due to missed assessments may have been attributed to this lack of awareness and interaction.

These findings highlight a possible relationship between the level of student engagement with online resources and their overall academic result. Across the online activities measured, namely the number of sessions logged, online assessments attempted, files viewed and messages read on the discussion board, the time spent on each activity was considerably longer for the High Distinction students. These results seem to be consistent with prior research which suggests that the online provision of course materials can have a positive impact on students' examination performance as reported by Perera and Richardson (2010).

Evaluation of Subject Website

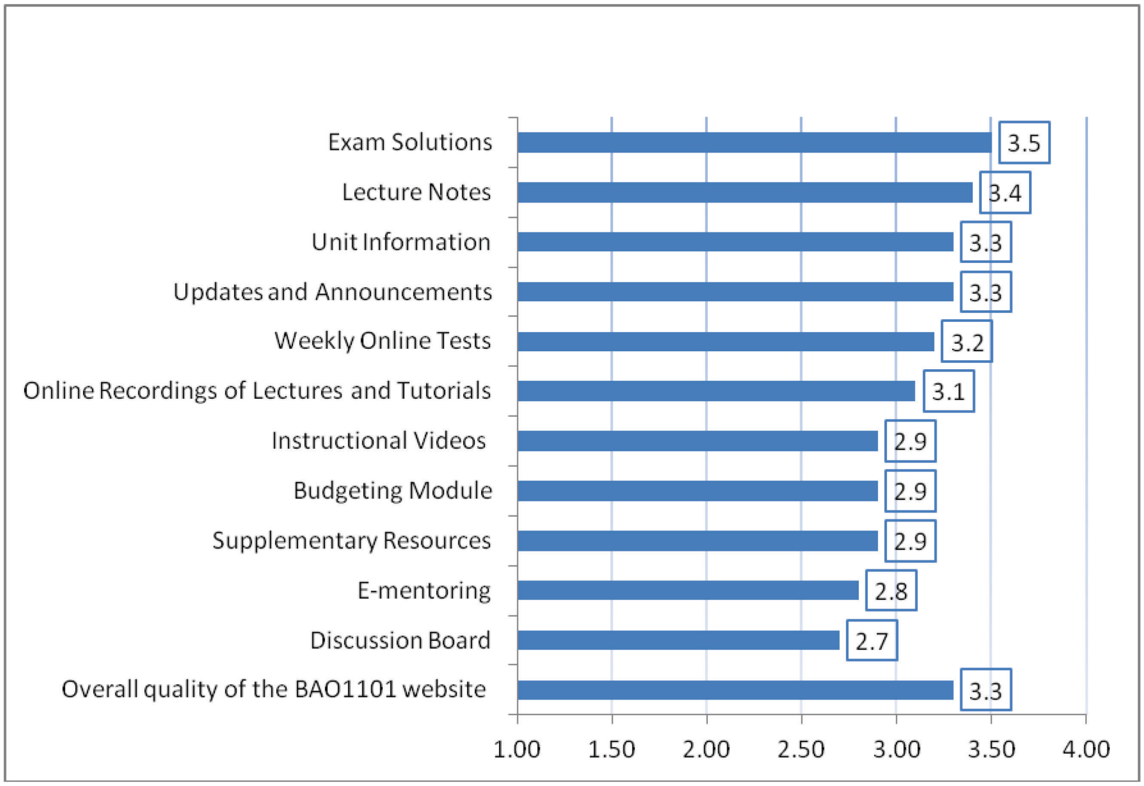
In Semester 2/2011, the final semester under review, the quality of the subject website and the usefulness of its main features was measured using a 4 point rating scale with 1=low, 2=medium, 3=high and 4 = very high, 'not applicable' was an option if students did not use the feature or did not perceive it to be useful. These results are shown in Table 6.

The most useful features were exam solutions (3.5) and lecture notes (3.4), closely followed by subject information, updates and announcements (3.3). Students also rated weekly online tests (3.2) and online recordings (3.1) as highly useful. These results are similar to previous research on the use of WebCT and its effect on student motivation which found that various design features of WebCT, such as the provision of lecture notes, use of bulletin board, online assessment significantly influenced the level of student satisfaction (de Lange, Suwardy, & Mavondo, 2003).

The features which enable students to communicate with each other and with teaching staff rated amongst the lowest; discussion board (2.7) and e-mentoring (2.8) but still regarded as moderately useful in their learning in this subject. This is similar to an observation made in a study conducted by Halabi and de Lange (2011) that students feel reluctant to engage in two-way online activities.

Students expressed a high level of satisfaction with its content and design, rating the overall quality of the subject website 3.3 out of a maximum score of 4.0.

Table 6 - To what extent were the following website features useful in your learning in this subject?



Limitations

It is acknowledged that there are various contributing factors other than the availability of additional online learning options that may influence the learning outcomes examined in this paper.

These results may have been affected by the relative quality of the resources available. There were some technical issues which compromised the audio and visual quality of the online recordings of lectures and tutorials. This may have impacted the students' responses to these options

Similarly, student views of traditional classrooms versus online learning resources may vary due the teaching provided in a face-to-face setting. Over the four semesters reviewed, there were on average, ten staff responsible for the teaching in this first-year accounting subject. Each of the staff differs in terms of his or her level of experience, teaching style and interpretation of the content. These factors may have also contributed the students' perception of their learning experience. Despite these limitations, the findings provide a starting point for further statistical analysis and future research.

Future Research

For possible future research, qualitative data collected from the student surveys conducted from Semester 1/2010 through to Semester 2/2011 but not included in this current paper can be used to identify the features recommended by students to further improve the quality of the subject website. It was of interest to find that the three new online options (recorded lectures, recorded tutorials, and an online tutorial) did not rate in the top five website features ranked by students as useful in their learning of this subject. The most useful features were Exam Solutions, Lecture Notes and Subject/Unit Information. If students perceived these basic needs as the most beneficial to their learning, it poses the question … as academics do we need to re-evaluate what we spend our time on in creating appropriate online support?

Conclusion

The results of this research indicate that despite having three new online options readily available via WebCT, there was still strong support for the traditional face-to-face approaches delivery as more effective learning options. From Semester 1/2010 through to Semester 2/2011, students ranked face-to-face lectures as the most effective learning option, closely followed by face-to-face tutorials. Of the online options, the viewing of recorded lectures rated the best. Although there was a continual increase in the mean score over the four semester period, it rated well below the face-to-face options.

To determine whether the online access to recorded lectures and tutorials had any impact in assisting the students' learning in this subject and potentially affecting their assessment outcomes, a review was conducted to compare the overall pass rates attained in this subject prior to WebCT and after the implementation of WebCT. Greer (2001) and Nicol (2006) suggest that change to assessment and innovative use of computer-based assessment may positively impact on learning.

It was found that the improvement was most significant from 2009 to Semester 1/2010 where the overall pass rate increased from 70% to 80% which coincided with the availability of online recordings lectures and tutorials. In Semester 1/2011, the overall pass rate peaked at 82% the highest attained in this first-year introductory accounting subject. By Semester 2/2011, this had dropped back to 72%. It was acknowledged that there is the possible interplay of different factors impacting on the overall pass rate. Longer working hours, larger proportions of non-accounting students with no previous accounting studies, low attendance rates and the quality of teaching were identified as factors which may adversely affect the overall pass rate.

An investigation of WebCT Course Management Statistical Tools revealed a positive relationship between the level of student engagement with online resources and their overall academic result. Across the key online activities measured, namely the number of sessions logged, online assessments attempted, files viewed and messages read on the discussion board, the time spent on each activity was considerably longer for the High Distinction students in comparison to failed students. It may be expected that there would be a correlation between the amount of time that students spent on their studies offline which would also affect these learning outcomes. Perhaps the effectiveness and attractiveness of online learning resources may be improved by increasing student interaction immediately after use of the online resource.

With the rapidly changing nature of accounting education, Rebele (2002) highlighted the importance of research specific to the effective use of technology in accounting education. In a review of more recent literature by Apostolou et al. (2011), the need for further research in this area is still relevant. By addressing some of the issues relating to student engagement with online resources and its impact on learning outcomes, these findings aim to contribute to this current gap in research.

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Biography

Lily Wong is the Unit Coordinator for Introductory Accounting, one of the largest student cohorts at Victoria University. Since undertaking her PhD, she has been actively involved in the research, development and integration of online teaching resources to improve the student learning experience for first year accounting students. Lily's contribution to teaching and learning has been formally recognised as a recipient of university and national awards. These include the Australian Awards for University Teaching in which she was a finalist; an Australian Learning and Teaching Council Citation for Outstanding Contribution to Student Learning; and recipient of the Vice-Chancellor's Peak Award for Excellence in Teaching and Learning.

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Digital Forensics Curriculum in Security Education

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Executive Summary

Information Security curricula usually cover traditional security topics such as network security, cryptography, and operating system security. As individuals and businesses have come to rely more heavily on computing technology, criminals also have turned their attention to such technology. Consequently, security requires developing adequate policies to protect the information assets, as well as gathering suitable evidence in case the matter ends in a court. Rapid advancements in storage technology have contributed to storing large volumes of data in small devices. Such devices could be hidden with criminal intent or are prone to being lost, thus exposing confidential information. In either case, we need to expose the students specializing in security education to both the technology and the legal aspects.

The author had the benefit of working closely with Information Security educators in the nation as part of the National Security Agency effort to develop curriculum that will address the security needs of the United States. In this regard the author developed a course in Digital Forensics as part of an Information Security Curriculum. When presentations were made in regional conferences about these efforts, the author found out that there was faculty in other institutions who were interested in starting a similar course in their institutions. They were also faced with similar financial challenges in developing a dedicated lab for Digital Forensics. Having taught this course twice, the author had ferreted out and obtained many inexpensive software packages to support the digital forensics curriculum.

In this paper, the author will share a sample undergraduate curriculum, resources needed to develop an inexpensive digital forensics lab, and steps to integrate this course in the InfoSec curriculum. As a motivation for this approach, first a brief history of Digital Forensics investigative history around the world is presented. This discussion identifies the major organizations that have contributed to the development of the necessary standards. The section on curriculum lays out the core learning objectives and the course content needed to cover these objectives. This is followed by details on setting up a Digital Forensics Laboratory. In this section, the author points out the usefulness of collecting hard drives from old computers and also the need to have several old computers available for teaching about the hardware elements. The section on Resources lists numerous free software resources as well as the ability to obtain commercial grade software from Access Data Corporation for free for instructional purposes. One of the key requirements in a digital forensics investigation is safe handling of evidence. This aspect is emphasized in detail about the Chain of Custody for data and presentation of

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evidence analysis to a court of law. The paper is concluded with lessons learned as well as what the next steps would be for future enhancements.

Keywords: digital forensics, curriculum, tools, security, evidence, data hiding, computer crime

Introduction

The use of computers is growing rapidly. For many years, the emphasis has been upon storing computerized data in a structured way so that the data could be retrieved readily when needed. Today we are able to capture data easily from places as diverse as points of sale and manufacturing centers. Because of the tremendous volume of data available today, search technologies have become popular to facilitate data retrieval from any stored place. This positive feature has also become a drawback, as people with criminal intentions are able to locate more information with ease.

The major types of computer crimes committed could be classified as:

- White-collar crimes (computers used to store and manipulate data, remote access)
- Violent crimes (premeditated planning using computers)
- Terrorism (planning, communicating and gathering intelligence about the target using computers)
- Espionage (surveillance and communication using computers)
- Counterfeiting (planning and design using computers)
- Drug trafficking (management of database of customers, suppliers, and financials)
- Pornography (storage of large volumes of video and photos in digital devices)

In criminal investigations, law enforcement often seeks the expertise of digital forensics examiners to inspect confiscated computer systems for evidence. For example, people involved in child pornography may create their videos using other devices but store their work in computers, hiding these files from discovery using ordinary tools. Thus, computer crime should not be thought of as one involving computers exclusively but also as one where computers are used as an accessory or tool. We use this broad definition here in discussing computer crimes.

The modes of computer usage in crimes could be described as:

- Target of crime (e.g., ATM machines)
- Instrument of crime (e.g., Internet fraud)
- Information repository for crime (e.g., money laundering schemes)

Investigating computer crimes and presenting evidence in a court has become an important tool in fighting such crimes. This field of investigation has come to be known as computer forensics. Today, given the growth of technology, people are using a multitude of digital devices, not just computers, to facilitate communication and commerce. As such, the study of Computer Forensics today is heavily involves the realm of, Digital Forensics which includes all forms of digital storage and retrieval. This new discipline is defined in various ways by different people. For our purposes we will use the following working definition adapted from Lunn's work: Computer Forensics involves the preservation, identification, extraction, and documentation of computer evidence so as to present in a court (Lunn, 2001).

Digital Forensics evolved as a discipline only within the past 20 years. To understand the beginnings of this discipline Whitcomb provides an excellent historical account (Whitcomb, 2002).

For many years, computer forensics was primarily done by law enforcement, and courts treated evidence generated by forensic investigations similar to the way they treated physical evidence. The FBI created the first systematic investigative team, called the Computer Analysis and Response Team (CART), in 1984. In 1993, the FBI organized the first International Conference on Computer Evidence. This conference was attended by representatives from federal, state, local, and international law enforcement agencies. Participants agreed that there were no formal standards for this forensics area. Consequently, follow-up conferences were held in U.S. in 1995, followed by similar conferences in Australia in 1996 and the Netherlands in 1997. This series of conferences eventually led to the formation of the International Organization on Computer Evidence (IOCE), which is plays a major role today. Even though CART and other FBI activities were instrumental in sowing the seed for the formal discipline of Computer Forensics, an FBI survey in 1995 showed that 70 percent of all investigative agencies were doing computer forensics work without a formal procedures manual. The IOCE, the FBI, and others have contributed to developing common standards for forensics examination. Much of the initial work in this area was done by Mark Pollitt and his associates (Noblett, Pollitt, & Presley, 2000). In spite of this progress, there still is no single recognized certification for forensic examiners. Yet, since one of the goals of digital forensics is to generate evidence for presentation in a court, having accepted norms is important for such evidence to be given appropriate weight.

As discussed above, the IOCE's efforts in developing common standards for computer forensic investigation around the world has been significant. In 1997, the IOCE issued a call for standards in gathering evidence. This was followed by a communiqué from the 1998 G8 summit emphasizing the need for international standards to combat computer crime. This resulted in the IOCE developing a standard and presenting it to G8 in 2000 (G8 Summit, 2000). One of the main contributions of this standard was in guiding a variety of groups, including first responders, to follow acceptable standards in gathering evidence. In the U.S., Regional Computer Forensics Laboratories (RCFL) were created by the FBI to support investigating computer crimes (RCFL, 2013). At present there are 16 RCFLs in the U.S. In order to exchange ideas among computer forensic investigators, besides the IOCE, the following three associations are making significant contributions:

- International Association of Computer Investigative Specialists (IACIS)
- High-Technology Crime Investigation Association (HTCIA)
- Computer Technology Investigators' Network (CTIN)

The discussion so far has been focused on explaining the development of digital forensics as a discipline. In the past, this field received the attention of law enforcement only. Over the past five years, this field has received increasing attention from academic institutions in the U.S., particularly Community Colleges. The importance of including Digital Forensics as a subject in an academic curriculum was articulated in papers by Yasinsac and Manzano (2001) and Yasinsac, Erbacher, Marks, Pollitt, and Sommer (2003). Yasinsac used the terminology Computer Forensics, which is subsumed by Digital Forensics. Chi (2009) presented details on the development of a laboratory for teaching Digital Forensics to undergraduate students. Interest in teaching Digital Forensics as part of the academic curriculum is prevalent in Europe, Australia, and Africa as well. We briefly present the details from published literature on Digital Forensics from these three continents. Anderson and his co-authors (2005) present details on their German and British experience in offering computer forensics courses. Their research indicates that in Britain the focus is on educating students "in using standard forensic tools, whereas the German case is more aimed at training students to build and improve standard tools." In the case of Australia, Lim (2006) points out the need for more computer forensics trained students. Lim's paper describes a six-dimensional knowledge model for computer forensics that deals with "categories of crime, computer technology, security, legislation, investigation process, and forensic tools." Stander and Johnston (2007) analyze the need for forensics curriculum in South Africa. They point out that types of computer crimes include hacking, denial of service, virus attacks, identity theft, cyber bullying and intellectual property theft. In their curriculum they introduce the concept of "End-to-

End Digital Investigation process," which includes all the traditional steps discussed later in this paper. Two other useful references based on US experience are the work of Austin (2007) in which he identifies several inexpensive tools to teach Digital Forensics and Batten and Pan (2008), who discuss their experience in teaching Digital Forensics at the undergraduate level.

The author has had the opportunity to develop and teach Digital Forensics as part of the Information Security undergraduate curriculum twice in the past three years. The course focuses on portraying the essential requirements needed to (1) monitor defenses set up for protecting networks and (2) bring any perpetrators of computer crime to justice. Toward this goal, the computer scientist must be aware of the legal requirements for obtaining, preserving, and presenting such evidence in a court. Such legal requirements are a necessary part of the course. At the author's institution, ethics topics are integrated in multiple courses. Consequently, many of the legal aspects associated with ethical situations, such as posed by Smyth v. Pillsbury (Standler, 1998), are covered in this course.

We are pleased with the success of this course. Our student survey for the course asked the students to rate the course's usefulness for understanding security issues. More than 80% of the students rated the course as very useful for their understanding of the security issues.

The sections below describe what has worked as an academic curriculum, how we constructed a laboratory with minimal cost, our lessons learned, and how other institutions might benefit from our experience.

Curriculum

Digital Forensics is offered as one of the five courses in an Information Security concentration in the Computer Information Systems undergraduate program. We offer this course in alternating years. A similar course is also offered in the Computer Science Masters program periodically. First, this course is enabling the InfoSec concentration to offer a total of five courses from which the students can choose four courses to meet the concentration requirements. From a curriculum perspective, this course gives the students an exposure to hardware aspects and teaches them how to use certain investigative tools and how to gather as well as protect evidence. We developed this course with help from Purdue University's Information Security program where multiple courses are offered in Digital Forensics in their Technology program. The first time we taught this course we offered a one credit course titled "A+ for Forensics." This course helped us build the necessary lab exercises and obtain the necessary laboratory resources, which we will describe later in this paper. We used this one credit course as a pre-requisite one time for the Digital Forensics course. Afterwards, we found out that it would be better to incorporate much of the content in the regular course in Digital Forensics, thus removing the pre-requisite. The course objectives we had were as follows. These are presented in line with Bloom's Taxonomy. Upon completion of the course the students would be able to:

- Describe the basic concepts of Digital Forensics.
- Explain the ways of gathering evidence.
- Explain the legal constraints of evidence collection.
- Show the implications of data access, storage and data hiding techniques.
- Differentiate data recovery methods using multiple storage devices.
- Compare the implications of privacy laws in the forensics context.
- Analyze the ethical aspects in dealing with Computer Forensics.

In trying to accomplish these course objectives we identified the following topics for the course:

- Introduction to Digital Forensics
- Computer Investigation approach

- Digital Forensics Technology
- Digital Forensic Tools
- Role of Operating System in Digital Forensics investigation
- Imaging Methods and Storage Technology
- Evidence collection
- Digital Forensics Analysis and Validation
- Recovering Graphics Files
- Evidence Dynamics and Evidence Preservation
- Network Forensics
- E-mail Investigations
- Cyber Crime
- Laws governing Evidence
- Privacy and Ethical aspects of Digital Forensics

These fifteen topics are particularly suitable for a 15-week semester course. The primary thrust of our course was in preparing the students to understand the legal requirements for gathering, preserving, and presenting evidence. As part of this goal we needed to expose the students to some of the hardware aspects, which many seemed to lack because of the heavy emphasis in our program on software. After an initial introduction to the hardware aspects, we looked at simple tools available widely for analyzing network communication.

Much of the course is devoted to understanding the legal requirements related to gathering and analyzing the evidence, having a chain of custody for the evidence, generating the necessary reports based on the evidence, and presenting the evidence in a court. In this connection we reviewed several court cases as to how they dealt with the evidence. Some of the important cases used in the review were NY vs. Ferber, U.S. vs. Frye, U.S. vs. Katz, U.S. vs. Kyllo, U.S. vs. Thomas (Legal, 2010). In this connection we also covered several federal laws concerning protection of children and privacy issues. These laws include the following:

- Sexual Exploitation of Children Act
- Child Protection Act
- Child Sexual Abuse and Pornography Act
- Child Protection and Obscenity Enforcement Act
- Child Pornography Prevention Act
- Child Online Protection Act
- Digital Millennium Copyright Act
- Family Education Rights and Privacy Act
- Electronic Communications Privacy Act
- USA PATRIOT Act of 2001

We devoted several class periods to discuss how cyber crime is committed and how network forensic techniques could be used to track criminals. In order for students to understand the practical aspects of digital forensics, we were able to visit one of FBI’s Regional Computer Forensics Labs (RCFL). On another occasion, we had a practicing attorney dealing with digital forensics cases present a talk about the legal aspects of evidence. On several occasions we brought up ethical issues that crop up in investigation and reviewed some ethics related cases. Another important topic that we covered in this course related to emails. This topic particularly attracted students’ attention because of their extensive use of a variety of providers for email service. We covered this material from an investigative aspect, using commercial tools such as FTK and Paraben Software. One important part of this discussion was in evaluating the amount of information hidden in email headers for investigative purposes.

Growth of storage technology has led to many small devices such as thumb drives and digital flash cards used in cameras holding large volumes of data. Further, improvements in storage technology such as SATA II have facilitated rapid data transfer between devices. Wireless communication has further facilitated storing data in remote locations using NAS and SAN technologies. From an investigative standpoint these are all challenges to be faced because these types of storage devices are not easy to locate. Moreover, tools such as Host Protected Area (HPA) enable the partitioning of hard disks into hidden areas that are not accessed by the operating system (Gupta, Hoeschele, & Rogers, 2006). We concluded the course with a study of how small electronic devices such as cell phones and PDAs are used extensively to communicate and how much information is stored in various log files relating to these small devices. Extracting such information requires a variety of specialized tools because there is no single standard used by the hardware manufacturers of these small devices. It is expensive to build the tool set to analyze all such devices. Overall, the course material coverage gave the students a sampling of technologies in use that could be abused by computer criminals and how specialized hardware and software tools could be used to extract such evidence directly from such devices as well as from other communication providers such as ISPs.

Laboratory

In order to give the students a strong foundation in digital forensics concepts and practices it is essential to have an opportunity to do hands-on practice. For this purpose a dedicated lab would help. At the least, the students should have the space and computers to open up and identify the inner hardware on a computer. It is our experience that getting used computers was not difficult but having the space to use as a lab might be the problem. Instructors planning a digital forensics course may have to focus on this to see if this resource could be made available.

We were able to find several spare computers and provided the students desk space to open the hardware to see the internals. One assignment involved changing the boot password by removing the battery powering the CMOS chip. These computers were also used to practice "bag and tag" of evidence. For three assignments, we used FTK software. We acquired six hard disks from external sources and supplemented them with a few more hard disks. Each hard disk was assigned to two students. A demonstration version of FTK is available for free from Access Data for teaching purposes. This software covers most essential aspects of a forensics investigation. Each student used the allotted hard disk to run the FTK software to find hidden and deleted files. Students also created host protected areas on their hard disk to hide files. Each student had to find the hidden and deleted files in other students' hard disks.

One of the major tasks of a computer forensic investigator is to find deleted files and files that have been altered to look like they are unusable. In this context it is important to note that there are certain powerful tools such as Evidence Eliminator (2013) which scuttle this aspect of an investigator’s work. When Evidence Eliminator is used to delete a file, then it leaves no trace of that file. The students were given an exercise to test this using both FTK and Evidence Eliminator.

Most criminals, especially people dealing with child pornography, tend to hide files in multiple ways. Some of these approaches may be as simple as changing the file type so that it does not draw the attention of the examiner or so that it will not be identified by the operating system as a file of a particular type. In the next several paragraphs, we will outline other methods of hiding files.

File Hound (2013) is useful free software that does a very good job of finding all image files in a storage device, irrespective of what was done to the file name. The assignment for this involved each student hiding a file in their hard drive and other students discovering such files. Much of the focus in this course was related to file systems in the form of locating and recovering files, viewing the file contents, checking for hidden storage spaces in hard disks, etc. An excellent resource to learn more about file systems is Carrier's book on File System Forensic Analysis (Carrier, 2005).

A fundamental rule in evidence gathering from a site where law enforcement people converge based on a search warrant is to make a bit-stream image of all storage devices found. A bit-stream image is a copy of all storage content bit-by-bit. This way all hidden and deleted files will be found. In order to make the evidence captured presentable in a court, the bit-stream image should be hashed using MD5 or SHA-1 method and a copy of the bit-stream image along with the hashed values embedded should be left with the owner of the data. A side benefit of bit-stream image is that it lends itself to easy searching for any specific sequence of characters. It is important to note that the hash value does not reveal any information about the original data. Students were given an assignment to demonstrate their grasp of this important aspect of evidence gathering. This is usually time consuming because large volumes of data may have to be copied.

One of the important things to follow with any captured evidence is chain of custody. This means that there should be complete documentation of every activity that was performed with the captured data. This trail should account for the entire period the data was under the control of the person gathering the evidence. Finally, after examining the captured data the examiner must prepare a detailed report indicating the conclusions that could be arrived at from the data. This report would form the basis for any expert testimony in a court.

So far we discussed a conventional laboratory environment. Bem and Huebner (2007) described a scenario where some of the forensic analyses could be done in a virtual environment. Their conclusion was that the virtual environment enables the investigator to gain greater experience in increments than a conventional one. This is another option instructors could consider in examining evidence.

Lessons Learned

In planning for this new course, we lacked the necessary laboratory resources needed for testing. By offering the one-credit course "A+ for Forensics" we were able to identify both the hardware and software requirements from a tools perspective. This led us to acquire the FTK package and the Read/Write blockers necessary to conduct a forensic investigation of a storage device. We were in the same situation as most institutions, where obtaining used hardware was not a major problem but finding financial resources to acquire new software was not easy. This forced us to look for free software tools. We were pleasantly surprised to find many tools with sufficient power to teach the basic forensic concepts. Over the past two years, with the increase in the number of academic offerings, companies such as AccessData have made available some free versions of their popular software (FTK, 2013). We have identified such resources in this paper.

Resources

The main aim of this section is to assist faculty planning to incorporate Digital Forensics as a course in their curriculum by identifying what types of resources are available, what they would cost, and how to obtain them. For this course, we acquired some free software tools as well as some commercial grade tools. We briefly describe each resource that could be obtained for free or for a minimal cost.

Hex editors enable the user to see both the bit values and ASCII values in one screen, line by line. There are several free hex editors available. Tiny Hex Editor is the one we used in our course (Hex Editor, 2013). Taft (2013) is a free tool that interfaces with ATA drives and retrieves a variety of information about the hard disk. It is also used to change the maximum addressable area, thus creating a HPA to hide data. Timestomp (2013) is a free tool used to modify the NTFS generated data about file creation, access, and modification timestamp values. Evidence Eliminator (2013) is a very powerful tool that completely eliminates all traces of a file. This works counter to what a forensic examiner would want; however, it is essential for the students to know such tools exist as well. This is inexpensive but not free software. File Hound (2013) is available free from CERIAS institute at Purdue University. This software will find all image files, irrespective of their type (JPEG, GIF, TIFF, PNG, etc) and whether the file header was modified or not. Sleuth Kit (2013) is free software that comes with the Autopsy Browser. Both are open source digital forensic tools that run on Windows and UNIX systems. They enable the user to examine a variety of file systems for evidence.

The three popular commercial tool sets are: FTK (Forensic Tool Kit) by Access Data, Encase by Guidance Software, and FRED (Forensic Recovery of Evidence Device) by Digital Intelligence. FTK is an affordable tool for academic institutions. FTK Imager is available for free, which will do many of the functions of the full version. In order to use the software tool, first a write-blocker kit is needed. The full kit (sturdy bright yellow box) costs around $600 but one could acquire just one write-blocker and the cables only from Access Data (FTK, 2013). A free version of FTK demo software is available from AccessData Corp. Encase is a powerful tool and costs significantly more. However, recently Encase (2013) has started offering academic institutions at a more reasonable rate. Interested instructors could contact Guidance Software directly for the details. All the functionalities that Encase offers for the teaching environment also are available from FTK. FRED (2013) is a hardware system with embedded forensic software. It is more expensive than FTK and Encase, but it has many useful features for forensic investigation of hard disks.

One of the main things done first in forensic investigations is in making a true image of the hard disk and other storage devices under investigation for the necessary evidence. All three commercial software mentioned above do this very effectively. However, there is a command in both Windows and Linux/Unix environments called **dd**. This free tool will also facilitate making a true image of a storage device. In preparing the material to cover these topics, several books were used. The publication details for these books are in the References section (Brown, 2009; Kruse & Heiser, 2001; Philipp, Cowen, & Davis, 2009; Phillips, Nelson, Enfinger, & Steuart, 2008; Shinder, 2008; Vacca, 2013).

In addition to these tools, we also examined many network communication tools. This category includes tools such as Nessus, Snort, and Wireshark. All these tools are free.

The tools identified above are widely used in forensic investigations and so they all have practical relevance. The Hex Editor and Taft are useful in gathering information about the storage aspects used to hide information. Timestomp plays a critical role in providing corroborating evidence in a legal setting. Evidence Eliminator's power is to illustrate how a criminal could eliminate evidence. File Hound is useful in detecting images that are hidden by altered file types that would be detected by the file system. Sleuth Kit's use comes in the form of providing evidence to back up a forensic investigation. Newer tools are constantly emerging as newer evasive techniques are developed by the criminal minds to hide evidence of crime. In this effort the work of NIST, in collaboration with the Law Enforcement Standards Office, to develop methodology for testing computer forensic software tools is significant. This resource is important for a forensic examiner to have confidence in the integrity of the software tool used for forensic analysis (NIST, 2013).

Future Enhancements

We have noted the wide popularity of small devices such as high capacity storage devices, powerful cell phones and the ability to access the Internet from mobile devices such as iPhones, iPads and other Smart phones. Also, the capacity of USB flash drives and digital camera flash cards exceed 16 gigabytes. Consequently, very large amounts of images could be stored in portable devices and hidden. It may be hard to locate these portable devices during an investigation but an analysis of the computer system would at least show the copying of large volumes of data to USB and fire wire based devices. This shows that a significant amount of evidence in investigations might be stored in small appliances. For this reason we plan to enhance our Digital Forensics Laboratory with the capability to examine and gather evidence from such small appliances.

Conclusion

Digital Forensics is an important area of study for information security students because, while computer forensic investigation does not prevent the crime from occurring in the first place, it serves as a powerful deterrent for the criminals to know that their acts can be discovered and prosecuted. Today, we find that financial fraud and child pornography are the two leading areas that are consuming much of the investigators' time. This problem is worldwide and, in addition to the social costs, involves several billion dollars in loss each year to legitimate businesses. The material we have presented above sheds much light into how these things could happen and how an alert person potentially could discover and track any crime committed.

The curriculum details presented in this paper could be of help for any instructor in developing a Digital Forensics course. Anyone planning to develop such a course should have good programming experience and understand simple hardware aspects in order to troubleshoot. A basic knowledge of how client/server systems operate would help in explaining network-based discovery issues. The person interested in creating such a new course would benefit if they start the preparation for the course content in spring semester in order to offer the course in the following fall semester. The main reason for this suggestion is that during the spring semester the instructor will be able to identify the hardware resources that could be gathered and there will be sufficient time to experiment over summer when laboratory demands will be less. From the student perspective, the course would be most interesting and effective if taken after they had courses in networking and database design and had significant programming experience. Typically students in the second semester of junior year would have the necessary background for succeeding in this course. This course would be an excellent addition to the Information Security curriculum. Students in Accounting and Criminal Justice programs would find this course very useful, as well. For accounting students the benefit comes from knowing how technology could be used to hide information so that they could be prepared to unearth hidden data in their audit. Students in Criminal Justice program would benefit by knowing how to handle evidence, the importance of Chain of Custody with computers and media, and what tools are available for the investigator to use to gather and reserve the necessary evidence.

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Biography

Srinivasan is Professor and Chairman of International Business and Technology Studies at Texas A and M International University. Prior to joining TAMIU he was at the University of Louisville from 1987 to 2010. He started the Information Assurance program at U of L in 2003. This program was designated a National Center of Academic Excellence in IA Education by NSA/DHS. His research interests are in Information Security. He has published several papers in both Mathematics and Computer Science. Currently he concentrates his teaching and research in Information Security related topics involving Social Media, Cloud Computing, RFID and SCADA. He is currently working on two books on Cloud Computing to be published in 2013. He is the recipient of several grants for security related projects. He spent his sabbatical years at GE, UPS and Siemens. He volunteers his time extensively for public education causes.

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A Database Practicum for Teaching Database Administration and Software Development at Regis University

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Executive Summary

This research paper compares a database practicum at the Regis University College for Professional Studies (CPS) with technology oriented practicums at other universities. Successful andragogy for technology courses can motivate students to develop a genuine interest in the subject, share their knowledge with peers and can inspire students to study the subject after they graduate from the university. One of the goals of the Regis database practicum is to inspire students to continue to study the subject of database technologies after they graduate (e.g., life long learning). A technology oriented practicum must provide students with the opportunity to develop both technological skills and soft skills (e.g., team work, effective communication, and work experience). The Regis database practicum fosters the development of soft skills by allowing students to volunteer in leadership roles, such as Project Manager, Technical Lead, and Project Lead. Students improve their communication skills by working on real-life software development projects with local stakeholders in the Denver area. Typical practicum team deliverables include functional requirements documentation, analysis and detailed design documentation, functional software, software test plans, status reporting of outstanding issues, and a final project report that summarizes the software development process that was followed during the practicum. The Regis database practicum also includes a database administration component in addition to a software development project. Students create and maintain the databases that are used for all of the undergraduate and graduate database courses within CPS for every 8 week term. Students also improve soft skills by working on the database support help desk on a weekly basis. Based on course evaluations, students have indicated that the Regis database practicum is a successful experience that helps them to fine tune their technical skills and to develop new soft skills.

Keywords: Active Learning, Practicum Experience, Database Administration, Database Application Development, Oracle APEX

Introduction

A practicum experience gives students real-world experience and bridges the gap between theory and practice. A practicum experience can strengthen a student's confidence by increasing their knowledge base about the subject matter and reinforcing core competencies learned in prior course work (Hendrick & Hendrick, 2011). Practicums are not a new concept for andragogy (teaching

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methods for adult education). Student participation in a practicum that provides a cooperative learning experience is considered an essential component of many graduate education programs. Practicum training has been successfully applied in the areas of Education, Business Administration, Oncology, and Family Counseling (Atta, 2012; Hendrick & Hendrick, 2011; Ratanasiripong & Ghafoori, 2009; Spring Arbor University, 2011).

For example, a practicum is a core component of the teacher education program that allows student teachers to acquire beginning teaching competencies (Atta, 2012). The experience of a teaching practicum enables student teachers to practice the delivery of lessons without using rote memorization. Social life skills are enhanced via interaction with the students. When teaching computer science to high school students, a practicum experience allows the student teachers to meet with students to explain complicated topics (Hazzan & Lapidot, 2004). The practicum also provides the opportunity for student teachers to practice their teaching skills via the delivery of a unit of instruction, assisting with computer lab work and tutoring students in small groups.

Another example of a practicum in the area of Business Administration includes a wide-range of practicum activities such as writing a business plan, managing a retail shop, creating computer record applications for non-profit organizations, coordinating a fund-raising campaign, and developing an inventory system (Spring Arbor University, 2012). Helfert (2008) describes a four month practicum that allows European students to analyze business problems and draw conclusions using scientific methods. Three examples of business information technology related practicum projects are:

- Investigation of Information Technology Support for detecting Money Laundering
- Review of the use of Service Oriented Architecture (SOA) in Supply Chain Management
- The effectiveness of Process Re-engineering in the Irish Health Care Industry

An example of a database practicum that is offered by Regis University (2013) is a viable and popular alternative to writing a thesis for two Master of Science (MS) degree programs: a Database Technology (DBT) program and a combined Software Engineering and Database Technology (SED) program. Students participate in the practicum for six months, complete two courses and earn six credit hours towards the completion of a 36 hour degree plan. Students are eligible to participate in the database practicum after they have completed the majority of their course work (30 credit hours).

A research objective for this paper is to investigate in more detail how the Regis University database practicum experience helps MS students develop both technical competence and soft skills. The concept of soft skills is described in the next section. The remainder of this paper will focus on practicums that are within Computer Information Sciences (CIS) disciplines and then will compare these programs to the Regis University database practicum.

A Practicum for Software Development Project Management

A practicum in the area of software development project management has unique properties because software development involves the transformation of intellectual ideas into a software product (Maqsood & Javed, 2007). Students are required to integrate business domain knowledge, apply technical knowledge, and work with people from different organizational units within a company. Maqsood & Javed (2007) suggest that students need a practicum environment that allows them to apply technical skills and develop soft skills (e.g., participation as a team player, use of management ethics and gain work experience in the corporate environment). To be effective software development project managers, students must learn how to:

- Comprehend basic and best practices (e.g. SWEBOK – Software Engineering Body of Knowlege, PMBOK – Project Management Body of Knowledge) that are followed during development, deployment and retirement of software systems.
- Follow system development methodologies and apply the appropriate software development tools during the development process.
- Understand the importance of project documentation, quality assurance, requirements analysis, data integration and configuration management.
- Adhere to the software development requirements that are provided by the stakeholders.

Typical project management practicum team deliverables include the following items (Maqsood & Javed, 2007):

- Functional requirements documentation
- Analysis and detailed design documentation
- Software test plans
- Status report of outstanding issues (bugs)
- A final project report that summarizes the software development process

Students are evaluated based on a variety of deliverables that include weekly status reports and meeting minutes, feedback from the project advisor and other team members, a project plan, comprehension of the domain issues, risk evaluation, project estimation, a quality assurance report, and a final project report.

In comparison, technical competence and soft skills are also important learning objectives for students studying database technologies at Regis University. The deliverables listed above are very similar to the Regis University database practicum project deliverables. In addition, Regis students follow a methodology that includes requirements gathering, analysis, design, coding, testing, and a final project report. Regis database practicum participants create project documentation at various stages throughout the development process.

Hands-on Learning to Teach Database Technology

A good example of teaching database technology to adult learners is provided by Moore, Binkerd and Fant (2002), who describe a Relational Database Management System (RDBMS) course at Texas A & M University Corpus Christi (TAMU-CC) that uses hands-on learning. The RDBMS course provides students with four academic credit hours. Students participate in three hours of lecture per week and two hours of lab work. The lab work includes instruction on how to use web development tools with databases. Although the students are exposed to programming languages such as C++ and assembly language in prior courses, this is the first class were students write code that interacts with a RDBMS.

The hands-on learning projects are based on applications that are needed by the university, therefore they can be considered service learning opportunities (Moore et al., 2002). For example, two recent projects included the development an art museum scheduling application and alumni registration application that interfaced with a RDBMS. The new alumni registration application captures demographic information about alumni (e.g., name, address, employer, major, and minor). The new art museum scheduling application allows web users to view schedules for exhibits, take virtual tours online and volunteer to conduct exhibit tours.

Ramakrishna (2000) also describes the importance of hands-on learning in the area of database technology andragogy. Ramakrishna noted that a majority of students (i.e., 87%) preferred a learning model where they actively participated by using a RDBMS in comparison to the traditional model of lecture and technology demonstrations by the instructor. Ramakrishna suggests that successful andragogy will result in the following:

- Students will develop an interest in the subject.
- Students will be given an opportunity to communicate their knowledge with their peers.
- Students will be inspired to study the subject after they have graduated from the university.

Ramakrishna (2000) describes how he added weekly hands-on homework assignments to the curriculum to help students comprehend the subject matter. Students were asked to summarize the material, highlight important points from the lecture, and answer descriptive questions that required further reading of the assigned text. In addition, programming assignments were given to the students to reinforce the technical concepts and to help the students to improve their technical skills. Ramakrishna (2000) surveyed 45 students (28 responded) regarding the addition of homework assignments to the coursework. A large majority of the students (96%) agreed (or strongly agreed) that the hands-on homework assignments helped them to understand the subject matter.

In comparison, database technology practicum students at Regis University are given the opportunity to perform a variety of technical tasks in the areas of Database Administration and Software Development. Students participate in additional training for Linux, Oracle Enterprise Manager (OEM), and Oracle Application Express (APEX). Students use Linux and OEM to create and maintain the Oracle databases for all of the 8 week database courses within the Regis University College for Professional Studies (CPS). Similar to the work that was described by Moore, Binkerd, and Fant (2002), the Regis students use Oracle APEX to develop web-based applications that benefit the university. Results from student follow-up surveys indicate that the additional technical training and hands-on experience within the database practicum is extremely beneficial.

Hands-on Learning within a Database Practicum

Meeker and Nohl (2007) emphasize the importance of hands-on learning as a supplement to passive learning when teaching database technology concepts to junior and senior undergraduate students. The database practicum course offered at Benedictine University (BU) provides students with exposure to additional perspectives that are not normally covered within the database systems course. The database practicum elective is one academic credit hour. Five different practicum experiences are offered to students and can be taken simultaneously with other computer science courses. Therefore, students have the option of taking additional practicum courses in the areas of Operating Systems, Computer Networks, Programming Theory and Numerical Analysis.

The BU database practicum consists of fourteen laboratory sessions that cover eleven independent projects (e.g. some projects span multiple weeks). Projects use different operating systems and DBMS, therefore the students are exposed to a broad spectrum of technology. For example, projects can include:

- Writing C# programs to access a Microsoft Access Database
- Installing a Microsoft SQL Server database and then creating database constraints, triggers and views based upon a data model (ERD)
- Conversion of an application program for one particular RDBMS to another RDBMS
- Security for the SQL Server database and SQL Injection examples
- Creation of XML files that can be stored in a RDBMS

Student reaction to the practicum experience was positive according to Meeker and Nohl (2007). Comments on an open-ended questionnaire indicated that the students thought the practicum offered a valuable experience because of the hands-on approach. The diversity of technology offered within the practicum appealed to the students. The additional technical work that the practicum required was not an issue for the students; in fact they seemed to enjoy it. The ability to "learn by doing", helped the students develop their problem-solving capabilities which in-turn boosted their confidence. Team work is encouraged in the practicum and students are able to reinforce their knowledge by discussing technical concepts with their peers.

In comparison, the Regis database practicum encourages the development of leadership skills and team work by allowing practicum participants to volunteer as project managers, team leads, and technical leads. Students are asked to peer review each other as a component of their final grade. Students rate each other based on the contribution to the work effort and the effectiveness of their communication skills. Providing leadership positions and problem solving opportunities are examples of the way that the Regis database practicum experience helps students to develop soft skills as described by Maqsood & Javed (2007).

Database Practicum at Regis University

As mentioned previously, Regis University (2012) offers a database practicum as an alternative to writing a thesis for two Master of Science degree programs: a Database Technology (DBT) program and a combined Software Engineering and Database Technology (SED) program. While participating in the practicum, students create and maintain all the databases that needed for the database courses offered each 8 week term (Regis University, 2012). The student database administrators (DBAs) also provide help desk support for database related problems that arise during the six month time period. DBAs support the help desk for one week at a time and rotate the help desk responsibilities so that everyone on the team has multiple opportunities to support the help desk. Issues that cannot be easily resolved by the student DBAs are escalated to the practicum technical lead and the database faculty. After completing the first Practicum course (3 credit hours), students are able to perform the following tasks:

- Connect to the Linux operating system using the Putty software tool and then enter Linux commands to manage database related files on the Regis Academic Research Network (ARNe) servers based upon the Linux training received during the course.
- Install and upgrade Oracle Database Management software on the ARNe Regis database servers using Linux operating system commands and utilities (e.g., Oracle 11.0.2).
- Create new Oracle user IDs and manage security for Oracle users. Create tablespaces and allocate file space for the new tablespaces. Drop user IDs when they become obsolete.
- Create new Oracle databases for use by the Regis Database students and instructors for each 8 week term.
- Create documentation for students and instructors to access the XEN Citrix Environment on ARNe and then access the Oracle database(s). Maintain documentation for the DB practicum, including procedures followed by the practicum participants.
- Communicate via email with Regis instructors regarding the new databases and Oracle user IDs that are created each term. Provide instructors and students with detailed connection instructions that include screen shots.

- Support Regis students and instructors via a help desk. Investigate and resolve any issues regarding the Oracle databases which can involve escalating critical issues to the DB Practicum technical lead and/or the DB faculty.
- Use Oracle Enterprise Manager (OEM) to monitor, evaluate, performance tune and administer Oracle databases based on the training received in this course.
- Monitor Regis ARNe server disk space usage and remove obsolete databases and data files.
- Develop web applications using Oracle Application Express (APEX) based upon the training received in this course.

Student DBAs are graded for the first DB Practicum course based on the following criteria (Regis University, 2012):

- 25% of the grade is based on the participation of the DBA in DB Practicum activities (e.g., attend weekly meetings, create and maintain databases, working on the help desk, solving technical problems that arise for students and faculty, etc.)
- 50% of the grade is based on the completion of the software training lab assignments for Oracle APEX, OEM and Linux for Oracle DBAs.
- 25% of the grade is based on a review by other practicum members regarding the DBA's contributions to the DB practicum and team work with the other DBAs.

During the second practicum course (3 credit hours), students participate in a real-life software development project that benefits an internal organization within Regis University (2012). After completing the second Practicum course (3 credit hours), students are able to perform the following tasks:

- Participate on a virtual software development team composed of people located at diverse geographical locations in the USA and Germany. They can make incremental contributions to the development of a high quality software application.
- Follow the DB Practicum software development methodology to analyze, design, code and test a web-based database software application on the Regis Academic Research Network (ARNe).
- Document, design and verify functional requirements, UML Use Cases, Sequence Diagrams, Entity Relational Diagrams (ERD) and Oracle Apex Web pages.
- Investigate and resolve challenging technical issues during the coding and testing phase of the software development project using the technical knowledge and expertise that was gained via earlier DBT course work.
- Create a new Oracle database to support the new Web-based software application. The database design will be based upon an ERD that is developed during the design phase of the software development lifecycle.
- Design and develop the Web-based portion of the application using Oracle Application Express (APEX).
- Document and adhere to software development standards for the new application.
- Develop and execute test plans to validate the new application. Debug and correct any application defects that are encountered during the test phase of the project.

- Create a project report that details specific contributions to the software development process, how the software adheres to the functional requirements and how they leveraged the DB Practicum methodology.

Student DBAs are graded for the second DB Practicum course based on the following criteria (Regis University, 2012):

- 25% of the grade is based on the participation of the DBA in DB Practicum activities (e.g., attend weekly meetings, create and maintain databases, mentoring new DB practicum members, working on the help desk, solving technical problems that arise for students and faculty, etc.).
- 25% of the grade is based on the completion of the software development assignment, quality of their work and if the application supports the functional requirements and Use Case diagrams.
- 25% of the grade is based on instructor review of the Final DB Practicum Report.
- 25% of the grade is based on a review by other practicum members regarding the DBA's contributions to the DB practicum and team work with the other DBAs.

Deliverables from the Regis Database Practicum are similar to what was described by Maqsood and Javed (2007):

- Functional requirements documentation
- Analysis and detailed design documentation
- Software test plans
- A final project report that summarizes the software development process

Discussion of the Regis University Database Practicum

Although the Regis University (2012) Database Practicum has successfully operated for 14 years, it recently has been enhanced to offer students a hands-on learning experience in the two areas of Database Administration and Database Application Development. Students are provided with additional technical training during the first 8 week practicum course in the areas of Oracle Application Express, Oracle Enterprise Manager, and Linux for Oracle DBAs. The practicum ranges in size from 13 to 19 students. Weekly practicum meetings allow students and faculty to discuss help desk issues, examine technical problem resolutions, discuss the management of the database environment, participate in project planning and the review of project deliverables. Maqsood and Javed (2007) emphasized the importance of a practicum environment where students can develop soft skills (e.g., team work, effective communication, and work experience). Students that participate in the Regis University DB Practicum develop soft skills via project collaboration that requires written communication using email and verbal communication during the weekly meeting. As mentioned previously, throughout the six months, students volunteer as the project managers, team leads and technical leads, thus allowing them to develop and demonstrate group interaction skills.

One goal of the Regis University College of Professional Studies is to inspire students to make a commitment to learning as a lifelong endeavor (Regis University, 2012). A goal for the Database Technology program is for students to demonstrate the ability to maintain technological competence in the face of rapid changes in database technologies and the field of information technology during their careers. Ramakrishna (2000) discussed the importance of helping students develop an interest in the subject and then continue to study the subject once they have left the university. Regis CPS Alumni are periodically surveyed about their continuing education pursuits and career advancement.

Therefore, the Regis database practicum strives to provide an academic environment that fosters the development of soft skills and life long learning. As part of the end of course survey that was taken in December 2012, students were asked "What course elements and/or facilitator practices contributed most to your learning?" The seven of the thirteen database practicum students that responded to the survey, replied as follows:

- The Hands-on assignments and the actual DBA type tasks.
- The labs were very relevant and I liked having other instructors cover their different sections - OEM, APEX, etc.
- Course Project
- Help desk experience and the development of the application
- Labs, Project tasks, and Final Report
- If this makes any sense, I really appreciated the "openness" of the program. Meaning that it is open to all levels of experience and yet still manages to offer something for everyone.

These comments are interesting because they indicate that students benefited from the variety of diverse tasks that comprise the database practicum curriculum. Meeker and Nohl (2007) describe the BU practicum options as a plethora of technical learning opportunities. The Regis database practicum is similar the BU practicum because it offers a variety of diverse technical challenges for students. Table 1 shows the results of the eleven statements that were presented as part of the database practicum course evaluation for the practicum that ended in December of 2012. Students were asked to rate each statement on a scale of 1 to 4 with 4 being the highest rating.

Table 1. Results from Database Practicum course evaluation in December 2012.

Questions	Statistics			
	Mean	Med.	Mode	S.D.
Course objectives were stated clearly.	3.9	4	4	.35
Course provided opportunities to practice ethical problem solving and decision making.	3.6	4	4	.49
Course expanded my knowledge of the course subject matter.	3.7	4	4	.45
Course activities helped me to understand the course learning objectives.	3.7	4	4	.45
Course challenged me intellectually.	3.9	4	4	.35
Course assessments gave me a chance to demonstrate my learning.	3.5	4	4	.76
Course was relevant to my professional goals.	4	4	4	0
Course helped me to be more effective at what I value.	3.6	4	4	.49
I consistently read the assigned readings.	3.5	3.5	3.4	.50
I asked questions in class or contributed to class discussions.	3.9	4	4	.35
I would recommend this course.	3.9	4	4	.35

Comments from the practicum participants were positive. Four encouraging comments are listed below:

> "Overall, the project proved to be an excellent introduction to web application design and implementation, along with an excellent vehicle to, once more, test my Oracle database knowledge and application (development) skills."

> "The project taught me a lot about the process of business analysis, gathering user requirements, designing use cases, design of a relational database and implementing a service-oriented architecture. I thought the project would be difficult, given the short time frame, but after regular meetings with the (stakeholders) staff, I gained a fuller understanding of how the existing system worked, and what new system features were going to be implemented. After repeated work efforts, the design began to take shape and the project seemed to take on a life of its own."

> "I have really enjoyed working with the Practicum team and especially stakeholders as we coordinated with the manager and her team to understand what they needed in future software. This has been an experience that would not have been possible if I had written a Thesis instead. The simple method of starting from ground zero and having to put it all together has been a tremendous learning experience. Everyone involved has been helpful in providing the team with the information needed."

> "Overall I believe that the goal of the practicum has been accomplished. I experienced many of the same issues participating on the team as I do on current software development projects or performing database administration tasks… While we are not too far behind our original timeline, as we begin testing, we may discover that there was some miscommunication among the developers concerning the requirements. This is natural and a normal experience for software development, and I believe a successful implementation of the goals of the practicum (was achieved)."

These comments from students indicate that the Regis database practicum is meeting the goals of enhancing technical skills and soft skills (human interaction and communication skills) as described by Maqsood and Javed (2007). Practicum students gained a better understanding of the software development life cycle and the issues that plague the software industry in regards to project management timelines and working with stakeholders.

Conclusion

Hands-on learning via a practicum experience is common place in many graduate education programs. In the area of software development, a practicum involves the transformation of intellectual ideas into a software product. A technology oriented practicum must provide both technological skills and soft skills. The Regis University Database Practicum includes both a Database Administration component and a Software Development component. Based on course evaluations, students have indicated that the Regis database practicum is a successful experience that helps them to fine tune their technical skills and to develop new soft skills.

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Biography

Robert (Bob) Mason joined the Regis University College for Professional Studies (CPS) as an Assistant Professor in January, 2011. He is the program coordinator for the CPS SCIS Database Technologies program. Prior to joining Regis as a full-time faculty member, he was an affiliate faculty member at Regis University for 10 years. In addition to teaching, Bob was employed by various Fortune 500 companies for 25 years as a Data Architect, DBA and Software Engineer.

Bob completed his Ph.D. in Computer Information Systems (CIS) at Nova Southeastern University. As part of his research, he designed and built a SOA Middleware prototype that was based on the 28 functional requirements that were provided by the panel of seven CIS experts. This prototype helps to resolve the interoperability gap challenges that exist between Learning Object Repositories & Learning Management Systems. He has a MBA with an emphasis in CIS from the University of North Texas. Bob has an undergraduate degree in Forestry Management and Business from the University of Tennessee. You can email Bob Mason at rmason@regis.edu.

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Design and Delivery of Technical Module for the Business Intelligence Course

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Executive Summary

IS programs are increasingly being called on to offer courses in business intelligence. This article presents the pedagogical design and the delivery method of a practicable technical module for a non-technically oriented Business Intelligence course. It is a tutorial for the instructors who wish to incorporate a practical technical element in their business-oriented Business Intelligence courses. The subject of the technical module discussed in this article is OLAP (Online Analytical Process). OLAP is the most commonly used technique of business intelligence but tends to be underemphasized in the existing textbooks and the pedagogy literature. The technical module of our Business Intelligence course covers four important parts: (1) a framework of OLAP strategy for business intelligence; (2) a guideline of OLAP practices in the Microsoft Office environment; (3) a set of elemental OLAP techniques including query, OLAP cube operations, statistical analysis, and data visualization; and (4) a technical assignment of OLAP. Our preliminary student feedback has indicated the usefulness of this technical module.

Keywords: Business intelligence, OLAP, course design, tutorial.

Introduction

IS educators are developing new IS courses to meet the needs of the IT job market (Helfert, 2008;Houghton & Ruth, 2010; Hunter, 2010; Tan & Venables, 2008; Topi et al., 2010). Business Intelligence (BI) is one of the emerging topics (Jafar, 2010; Presthus & Bygstad, 2012). In its broadest definition, BI is a conceptual framework for decision support. It combines IS architecture, databases, analytical tools, and applications (Raisinghani, 2004). Given the breadth of the topic, it is natural that there are a variety of approaches to the pedagogical design of this course. Generally, the design of the BI course can be placed in two major categories: non-technical and technical.

In a non-technical BI course, students study BI cases (e.g., Howson, 2008; Laursen & Thorlund 2010; Loshin, 2003; Williams & Williams, 2007). Students in these courses typically learn the value of BI for business and receive a non-technical overview of a variety of BI techniques such as OLAP (online analytical process), data mining, text mining, and others. In this approach, students learn that BI has created great opportunities for organizations to utilize massive data to support decision making. Students acquire a general concept of BI techniques, but are not required to perform technical exercises or to conduct technical projects. On the other hand, in a technical BI course, students are expected to master the implementation and application of the various technologies supporting BI (Shmueli, Patel, & Bruce, 2007).

Given the restricted number of elective courses in the IS curricula, it is ideal to have a single integrated BI course that integrates the two approaches. However, the textbooks to meet this demand are scarce. In our experience, Turban, Sharda, Delen, and King's (2011) textbook is the only widely circulated textbook that is suitable for a single business-oriented BI course with adequate non-technical and technical modules. The non-technical module of Turban et al.'s textbook covers the major concept of BI and business cases of BI applications. The technical module includes online access to data mining tools and BI software. The technical module allows students to practice data mining with neural networks, text mining, and statistical analysis.

When using Turban et al.'s (2011) textbook, we found that the advanced data mining techniques, such as neural networks and text mining, were too sophisticated for business students to understand even though students have already been introduced to statistical analysis used in BI in their required business statistics course. OLAP is underemphasized in the Turban et al.'s textbook, and hands-on material of OLAP is completely absent there. In fact, few available textbooks offer the OLAP hands-on material that goes beyond a concise introduction. Although a number of BI pedagogical papers (Mrdalj, 2007; Negash, 2004) provide overviews of BI courses, the pedagogical design and teaching material of OLAP for an integrated BI course are virtually missing in the IT education literature. Due to the widespread reliance on OLAP in BI, its absence in typical IS BI course designs appears to represent a serious shortcoming (Howson, 2012). Hence, the development of a practicable technical module of OLAP for the integrated BI course is imperative. This article describes the design and the delivery of a technical module of OLAP for our BI course in detail. Indeed, this article is a tutorial for the instructors who wish to incorporate a practical technical module in their business-oriented BI courses. The rest of the article is organized as follows. The next section describes the design of a framework of OLAP strategy. The third section explains the Microsoft Office environment for OLAP. The fourth section illustrates the elemental OLAP techniques. The fifth section describes our experience teaching the OLAP module, and the final section summarizes this tutorial.

Design of Framework of OLAP Strategy

An OLAP tool is typically available in almost every major BI suite system on the software market (Howson, 2012). The OLAP techniques not only lays a foundation for students to learn other BI approaches (e.g., data mining using artificial intelligence), but also helps students develop a better understanding of the general concept of BI. The technical module discussed in this article starts with a framework of OLAP strategy for BI.

A key point that students must learn is that data and the BI tools, including OLAP, do not generate meaningful knowledge automatically. Users require *a priori* knowledge of the business context and pertinent objectives of the analytical process to successfully employ BI. As a given data set can be viewed from many standpoints, an effective BI analysis must meet a clear business objective (Olszak & Ziemba, 2012). Therefore, the first subject of OLAP is a user-centric framework of BI strategy development. First, in order to effectively employ OLAP, the user must be a business insider who understands the specific context of business. The business users should have hypotheses about the type of information likely to be useful and how it might be employed in decision-making. Second, as there are virtually infinite ways to conduct OLAP, users' objectives for the specific analysis should be established prior to conducting OLAP. Third, as the data available for OLAP could be extremely large, it is crucial for the user to select a set of limited data and optimize the utility of the data set for the proposed OLAP analysis. Finally, as there are a variety of OLAP techniques, consideration should be given to the selection of techniques appropriate to the study objectives and the skills of the individuals who will be conducting the analysis. The emphasis of the technical module presented below is to provide students with basic skills so they can participate in choosing appropriate techniques. Overall, OLAP is not a one-shot operation, but is a trial-and-error process.

To assist students to learn the conceptual framework, we have created a diagram that highlights the aspects of OLAP strategy development as illustrated in Figure 1.

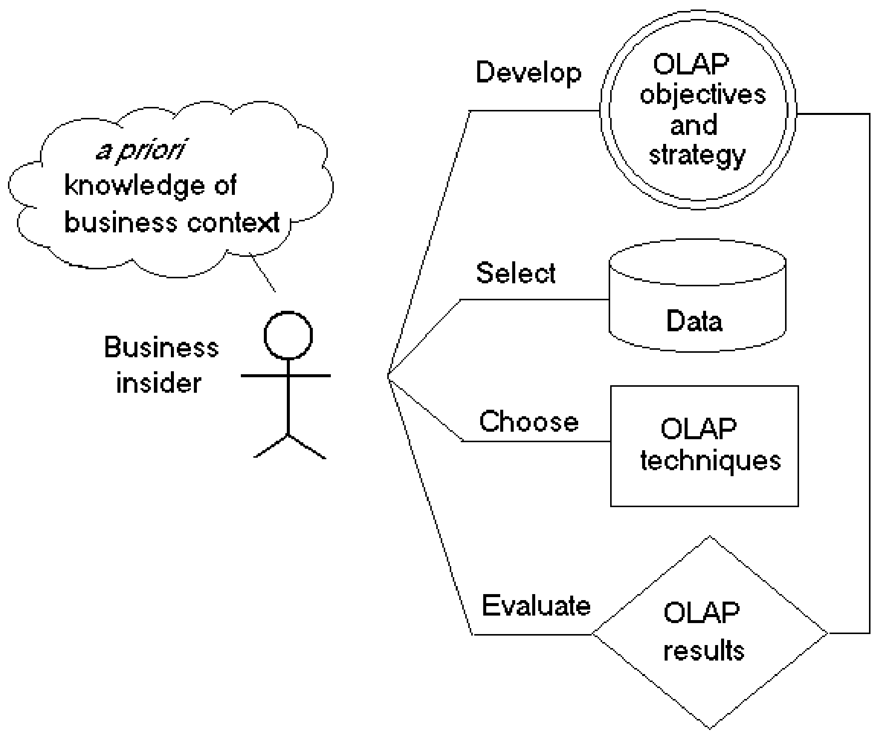

Figure 1. User-Centric Framework of OLAP Strategy Development

Generally, an OLAP strategy is a set of generalized or coarse hypotheses in the user's mind that OLAP processes are used to verify or disprove. Clearly, an OLAP strategy highly depends upon the business context, and there is no single formula for setting up the OLAP strategies. Nevertheless, we provide a set of common guidelines for the OLAP strategy development, as listed below.

- Focus on the critical factors of the business, potential problems and possible opportunities;
- Focus on the key performance indicators;
- Find correlations or associations among data relating to critical factors and key indicators;
- Find exceptional facts;
- Detect abnormal observations;
- Detect time-dependent trends, short-term, medium-term, and long-term;
- Verify or disprove the outcome of a business decision or a business action; and
- Verify or disprove a novel idea.

Design of Computational Environment of OLAP

Microsoft Office Environment for OLAP

The second subject of the technical module is the computational environment of OLAP. Given the trial-and-error nature of OLAP, OLAP heavily relies on the human-computer interaction. Hence, user-computer interface is an important factor in OLAP. Many users are passionate about the features of spreadsheet integration in Microsoft Excel, leading to Microsoft Office becoming a widely-used BI tool (King, 2009). Many leading OLAP products, such as SAP Duet and SAS, use Excel as their user-computer interface. Microsoft Excel itself has essential OLAP functions to meet the challenge of BI. Microsoft Office is available at almost every educational institution as a necessary computing tool for business students and, thus, is an ideal computational environment for us.

This section explains the Microsoft environment supporting OLAP and introduces key OLAP concepts. Microsoft Office includes Microsoft Access, an end-user oriented database management system. Microsoft Access is connected to Microsoft Excel through the internal database connection. One can input data in the Access database form to Excel without setting ODBC (Open Database Connectivity), and the operation of data input from Access to Excel is seamless. More importantly, Excel and Access use a common form of database queries which is a part of OLAP. In our OLAP environment setting, Access database is employed to explain the data source input, but the knowledge of relational database is not a prerequisite of this technical module for students.

We have created a diagram to display the components of Microsoft Office OLAP environment to students, as shown in Figure 2. The non-shaded parts in Figure 2 are relevant to the present context of OLAP hands-on practice; that is, data cube of Access database, Excel pivot table, Microsoft Query, common spreadsheet functions, data presentation chart, and data statistical analysis tools are the major components of the technical module.

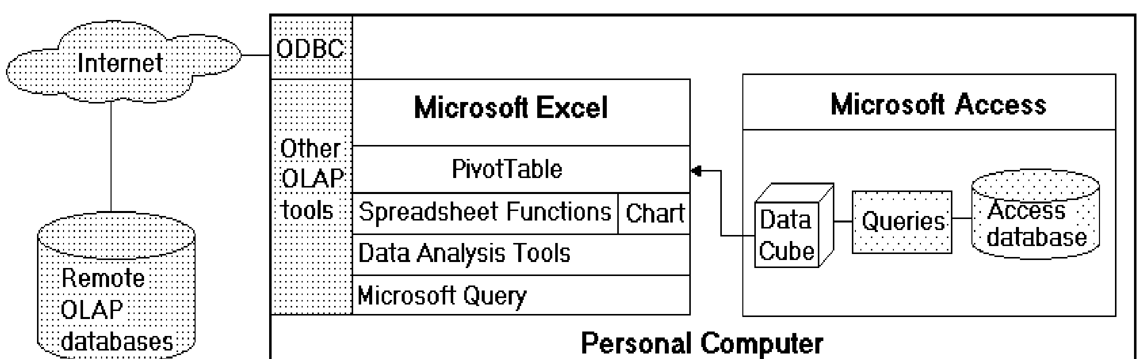

Figure 2. Microsoft Office Environment for OLAP

Data Cube for OLAP in Microsoft Office

Typically, the data used for OLAP is a high-dimensional data set which describes the facts with various attributes such as what, who, where, when, how, etc. A high-dimensional data set is called a data cube. The data cube used for OLAP is also called OLAP cube. The entity-relationship diagram shown in Figure 3 describes a data cube. This style of entity-relationship diagram for data cube is called star schema because there is the fact table (i.e., the data cube) in the center surrounded by several dimension tables. The three-dimension data cube actualized with data is illustrated in Figure 4. A data cube can be generated directly in Microsoft Access through a query, and can then be imported into Excel for OLAP. For students to practice OLAP in Excel, a small sample data set as illustrated in Figure 4 was created in the Microsoft Access form.

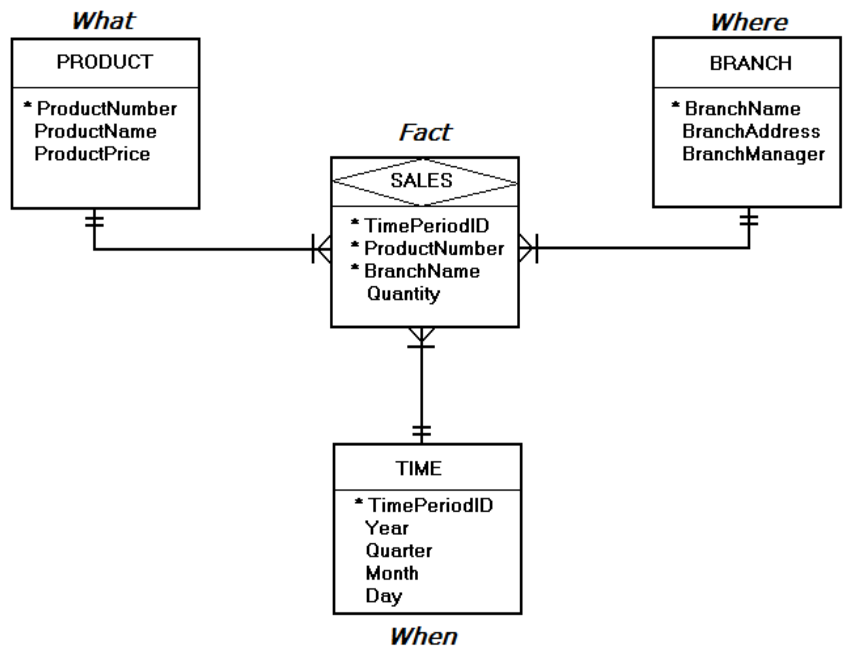

Figure 3. Sample Star Schema for Data Cube

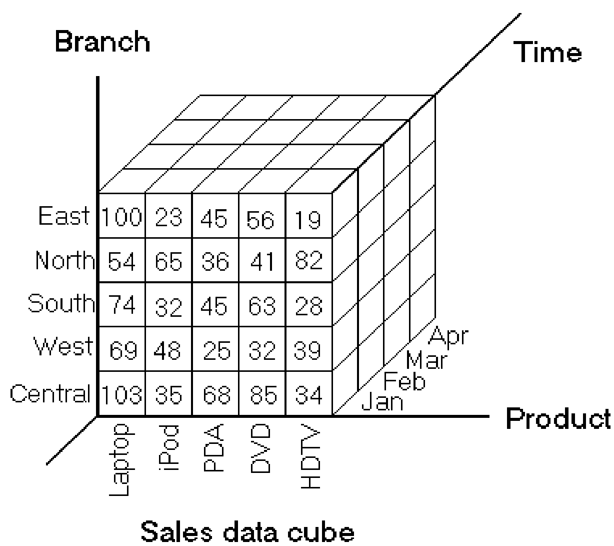

Figure 4. Data Cube with High-Dimensional Data

A data cube is stored in the database as a two-dimensional table that arranges the high-dimensional data in a certain way. Because human brains have difficulties in processing high-dimensional data by using a flat two-dimensional table, OLAP tools employ pivot tables to represent high-dimensional data. A pivot table is a set of two-dimensional tables that are recursively embedded at each level of each of the dimensions, as illustrated in Figure 5. As shown in Figure 5, the Sales related to Time and Product can be represented by a two-dimensional table that has the Time dimension for the rows and the Product dimension for the column. For the additional dimension of Branch, two-dimensional tables with Time and Product are generated at each branch, and a larger two-dimensional table with the Branch dimension for the column is created. The larger table is the pivot table representing the Time, Product, and Branch dimensions. The large two-dimensional pivot table embeds the smaller two-dimensional table for each branch. If there is an additional dimension (say, Chanel (*how*)), an additional pivot table can be generated for each level of Chanel (e.g., Online, Mailing, Phone, Store), and an even larger pivot table can be created to represent the four dimensions.

Sales						
		Product				
Branch	**Time**	Laptop	iPod	PDA	DVD	HDTV
East	Jan	100	23	45	56	19
	Feb	74	53	33	24	31
	Mar	28	38	26	54	29
	Apr	76	74	34	32	53
East Total		278	188	138	166	132
West	Jan	69	48	25	32	39
	Fab	49	23	43	26	38
	Mar	66	45	78	86	74
	Apr	63	13	15	47	23
West Total		247	129	161	191	174
North	Jan	54	65	36	41	82

Figure 5. Pivot Table for a Data Cube

To conduct OLAP in Microsoft Office, one must create a pivot table in Excel that imports the data cube from a database. Access database is used for this technical module for simplicity. Suppose the data cube has been generated and is stored in an Access database as a database table. Start Excel, click on `[Insert]` on the ribbon, and then click on `[PivotTable]`, the Create Pivot Table pane will show up. Choose `[Use an external data source]`, click on the `[Choose Connection]` button, and the `Existing Connection` pane will show up. Click on the `[Browse for More…]` button, find the Access database for downloading, and click on `[Open]` to connect the database. After connecting to the database, the data cube table in Access can be selected in the `Select Table` pane, and can be imported in the `Create Pivot Table` pane. Finally, the `PivotTable Tools` window allows the user to make the pivot table ready for OLAP.

Clearly, a database can contain many data cubes. As discussed in the second section, the selection of a data cube for an OLAP practice depends on the OLAP strategy. The selected data cube for the OLAP task is the OLAP cube. Figure 6 shows the pivot table of a sample OLAP cube that is included in the technical module for students to practice simple OLAP tasks, as discussed in the next section.

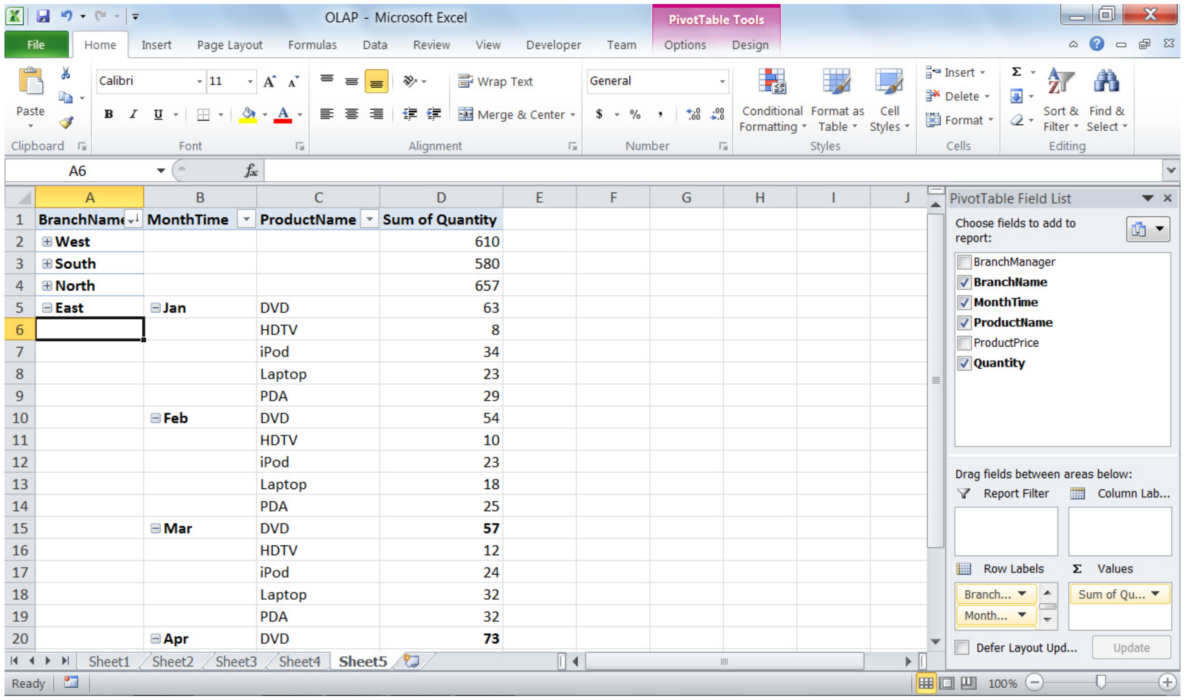

Figure 6. Pivot Table in Excel Implements OLAP Cube

Design of Elemental OLAP Techniques

Given the OLAP cube, one can use a variety of techniques to find interesting facts that meet the OLAP objectives. The next subject of the technical module is to introduce important OLAP techniques to students.

Elemental OLAP Techniques

An OLAP task can be accomplished by moving through different paths and by using various techniques. It is important for students to learn the elemental techniques of OLAP. An elemental OLAP technique is a basic technique of OLAP that can be combined with other elemental OLAP techniques to become a more sophisticated OLAP method. Four elemental techniques of OLAP have been identified for the technical module. They are query, OLAP cube operation, statistical analysis, and data visualization. A complex OLAP task can be accomplished by using a combination of these elemental techniques. To help students learn these elemental techniques, this section includes an OLAP prototype for each of the four elemental techniques. An OLAP prototype of an elemental technique is a template of basic OLAP tasks that can be accomplished by applying the elemental technique to the sample OLAP cube shown in Figure 6. An OLAP prototype is concise and can be practiced and imitated by students to develop the OLAP skills. Next, the four elemental OLAP techniques and their prototypes are discussed.

Query

A query is a set of instructions for processing the data with any dimensionality to extract useful information. One can create queries using SQL or QBE (Query By Example) in Excel or in Access. Using queries, one can find needed facts from the OLAP cube though selecting the data and defining the query criteria. Simple functions of queries include select, sort, group, filter, etc. Sophisticated queries can provide information concerning correlations among data.

The basic OLAP task prototype for students to learn and practice query is:

[Branch] has the highest sales of [Product] in [Time Period], in comparison with [Other Branches].

We provide detailed steps to use the Microsoft Query window in Excel for students to develop queries. Suppose the OLAP prototype is actualized to "*find Laptop top selling months and the responsible branch.*" One may set the query criteria, such as "`Product = 'Laptop' and SalesQuantity >30`", in the Microsoft Query window to run the query on the selected data set, and the query will find the result similar to the one shown in Figure 7. The fact revealed by this simple OLAP task using the query elemental technique would be:

"*East Branch had the highest sales of Laptop in both March and April, although other branches (West and Central) had the same sales levels in one of the two months.*"

This section sets three learning goals for students. First, students shall be able to use the query technique in Excel for OLAP. Second, students shall understand the types of basic OLAP tasks as articulated in the prototype that can be accomplished by queries. Third, students shall be able to extend the OLAP prototype to add conceivable meaningful facts. For example, a student might want to extend the OLAP prototype to find out the lowest sales of products in alternative months.

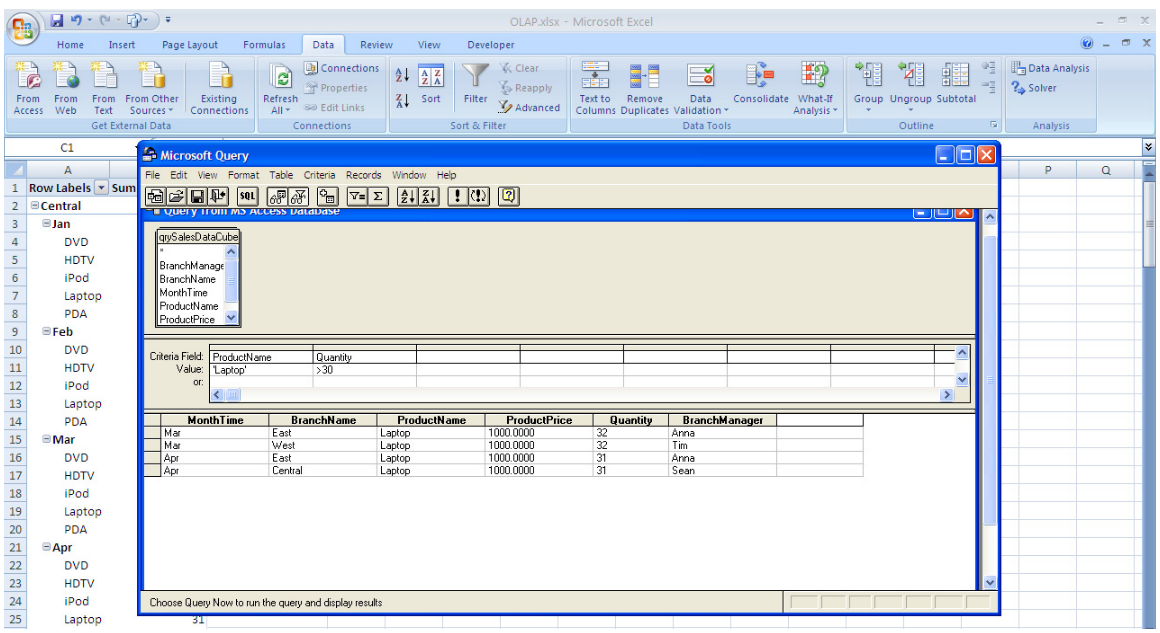

Figure 7. Query

OLAP Cube Operations: Slicing, Dicing and Drill-down

The OLAP cube can be manipulated to help reveal interesting facts and relationships in the data. This part discusses three techniques for manipulating an OLAP cube: slicing, dicing, and drill-down. Slicing is to reduce the dimensionality of the OLAP cube by fixing the level(s) of one or more dimensions to create slices. Figure 8 illustrates slicing.

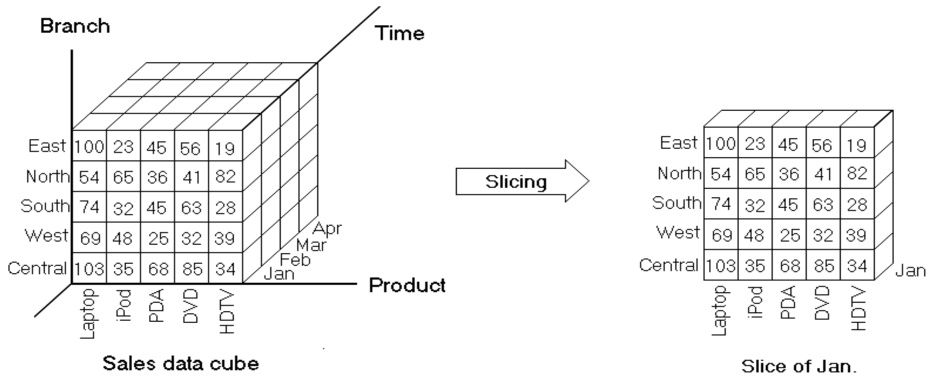

Figure 8. Slicing

Dicing is to divide the OLAP cube into sub-cubes (so called dice) for comparison. Figure 9 illustrates dicing.

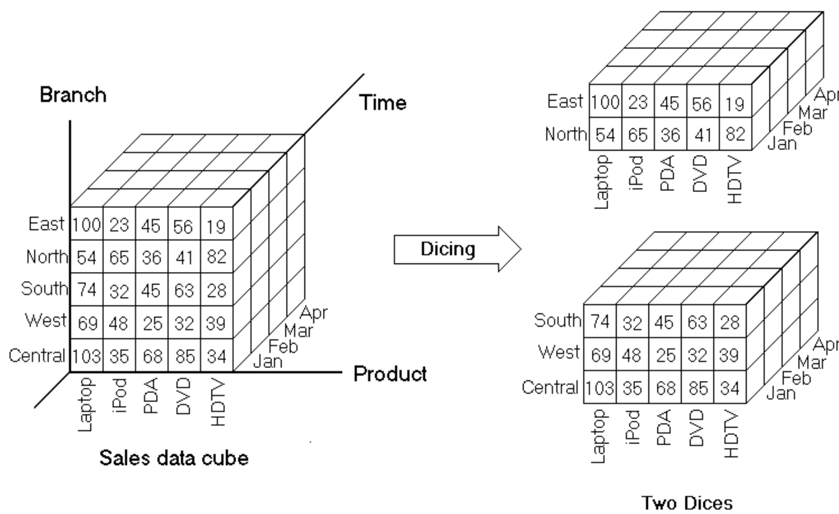

Figure 9. Dicing

The operations of slicing and dicing make the OLAP cube smaller to reveal detailed information. A pivot table can be used for slicing and dicing operations through the `[PivotTable Tools]` in Excel. The expand-collapse button (with the plus/minus sign) next to the item is used to expand (for the insertion to the slice/dice) or collapse (for the deletion from the slice/dice) the data item. Figure 10 shows an example of using the expand-collapse buttons to create a slice for Sales of East Branch in March and April.

A drill-down process is a combination of slicing and dicing with other techniques (such as queries and statistical analysis) to investigate information in increasing details. This part includes a basic OLAP task prototype for students to learn and practice OLAP cube operations and drill-down as follows.

[Branch] has significant increase of sales of [Product] in [Time Period] compared with [Time Period] by [Percentage].

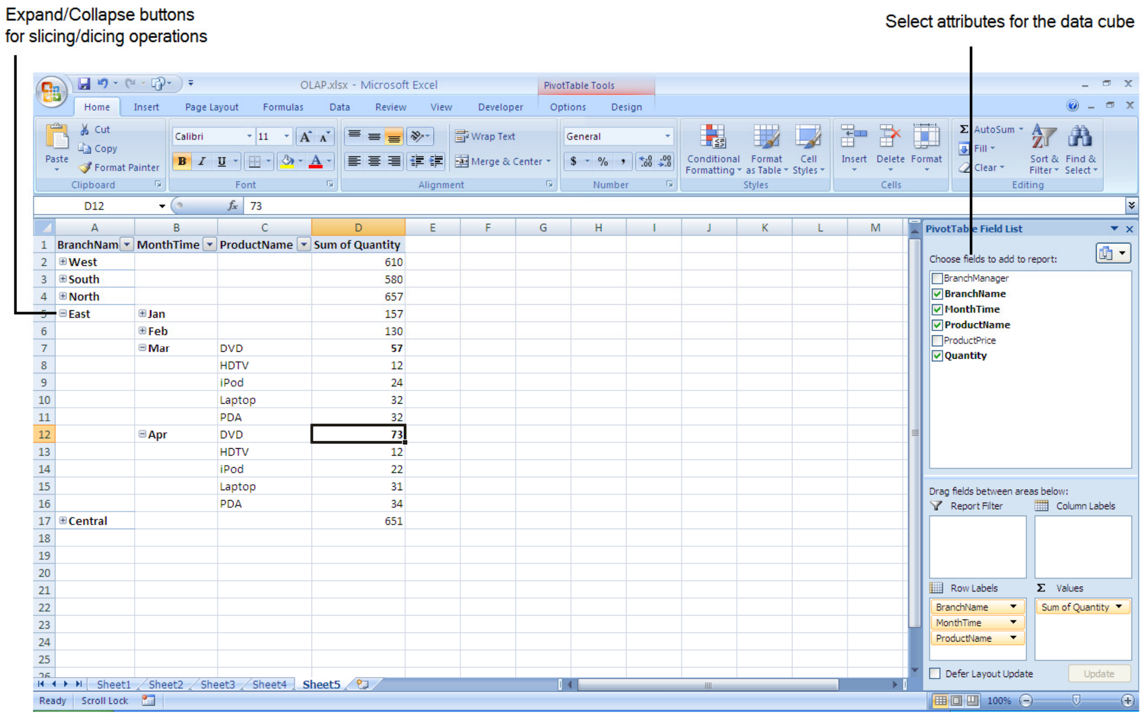

Figure 10. Slicing and Dicing in Pivot Table

One can apply the slicing and dicing operations to the data of the pivot table shown in Figure 10 and use a simple calculation to reveal such fact for this OLAP task as:

"*East Branch has a significant increase of sales of DVD in April compared with March by 28% ((73-57)/57).*"

This section sets three learning goals for students. First, students shall be able to perform slicing, dicing, and drill-down operations in Excel using a pivot table. Second, students shall understand the types of basic OLAP tasks as articulated in the prototype that can be accomplished by OLAP cube operations. Third, students shall be able to extend the OLAP prototype to add conceivable meaningful facts that can be revealed through OLAP cube operations.

Statistical Analysis

Excel has a package of common statistical analysis tools called `Analysis ToolPak`. Normally, one needs to active the statistical analysis tools by using `[Add-in]` in the `[File]-[Options]` menu so that `[Data Analysis]` will appear on the menu of `[Data]`. OLAP is supported by statistical analysis. Statistical analysis in Excel includes descriptive statistics (e.g., Sum, Min, Max, and Average), *t*-test, *z*-test, ANOVA, MANOVA, regression, etc. It is difficult to apply data analysis directly to the pivot table. One needs to take advantage of the copy-paste operation in Excel to copy the needed data set from the pivot table and to paste it to a separate sheet before applying the data analysis to the new table.

This section includes a basic OLAP task prototype for students to learn and practice statistical analysis as follows.

The difference of sales between [Branch A] and [Branch B] is statistically significant/insignificant given [Statistical Test].

An example of statistical analysis for OLAP is shown in Figure 11. The sales data of West Branch as well as South Branch are copied from the pivot table, and *t*-test is applied to the extracted data sets. The statistical analysis result reveals the information for this basic OLAP task would be:

"The difference of sales between West Branch and South Branch is insignificant, although the average sales of West Branch is slightly higher than sales of South Branch by 5% ((30.5-29)/29)."

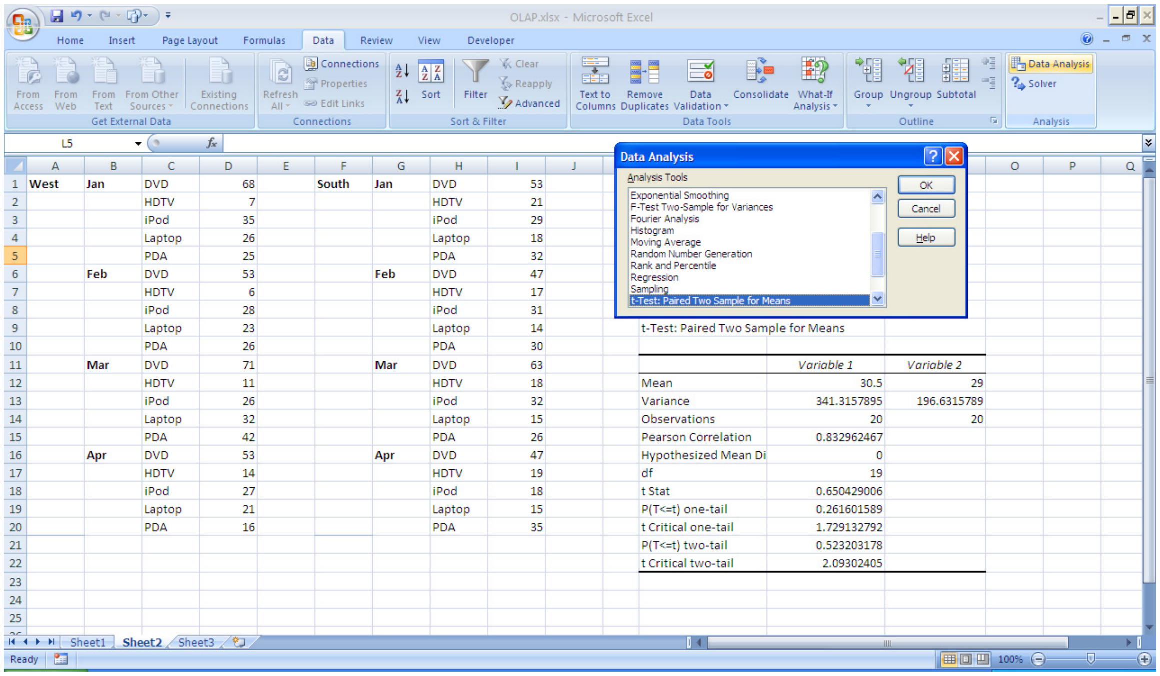

Figure 11. Statistical Analysis

This section sets three learning goals for students. First, students shall be able to use basic statistical analysis tools learned from the statistics course for OLAP. Second, students shall understand the types of basic OLAP tasks as articulated in the prototype that can be accomplished by statistical analysis. Third, students shall be able to extend the OLAP prototype to add more statistical analyses.

Data Visualization

Business graphics (line chart, bar chart, pie chart, etc.) are commonly used for data visualization to support human cognitive activities in analytical processing. The major purpose of the use of business graphics in OLAP is to effectively support comparison, trends tracing, pattern discovery, and exception detection. Excel has good data visualization functions with a variety of charts. This is one of the important features of Excel as the user-computer interface for OLAP. There is a PivotChart function in Excel. However, the ordinary Chart function is easier to use and understand.

This section includes a basic OLAP task prototype for students to learn and practice data visualization as follows.

The pattern of sales of [Product A] is similar/dissimilar to that of [Product B] during [Time Periods].

Given the sample OLAP cube, the data of sales of the four products over the past four months are copy-pated to a new data sheet. By using the Chart Tools functions, one can generate line charts to make a comparison of the sales of products over the time period, as shown in Figure 12. The data visualization result reveals the information for this basic OLAP task would be:

The sales of all products have the similar sales pattern over the past time periods. The contributions of each product to the sales seem to be stable.

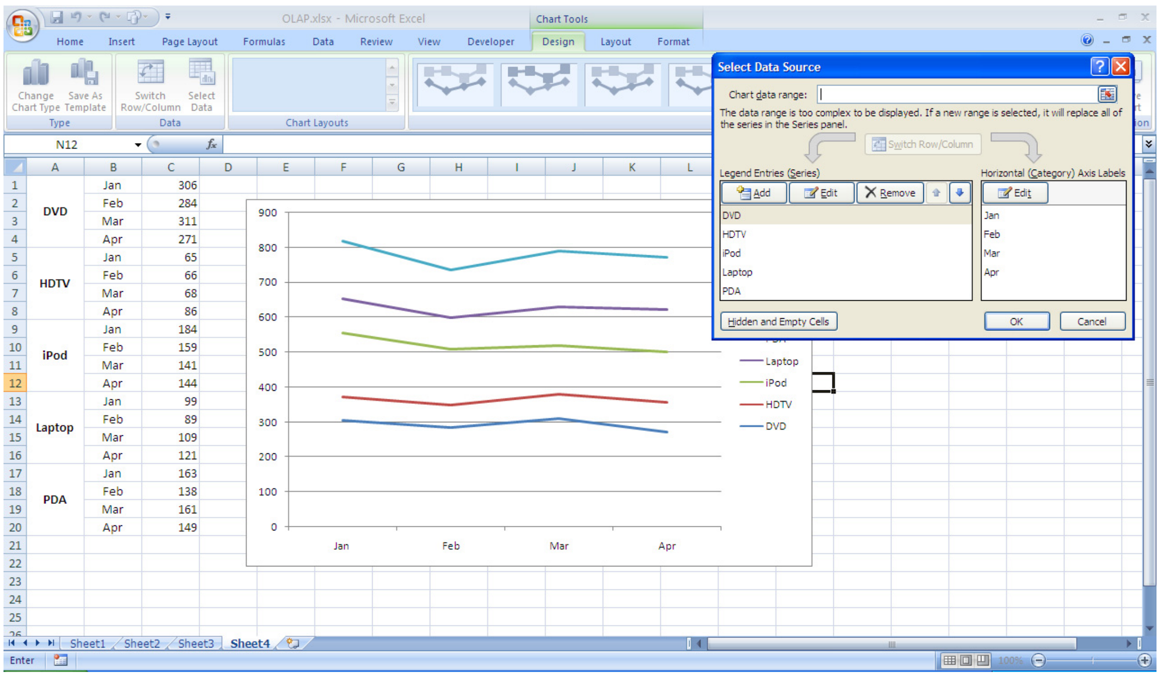

Figure 12. Data Visualization

This section sets three learning goals for students. First, students shall be able to use data visualization methods in Excel for OLAP. Second, students shall understand the types of basic OLAP tasks as articulated in the prototype that can be accomplished by data visualization. Third, students shall be able to extend the OLAP prototype to display various data patterns and comparisons by using a variety of business graphics.

Delivery of the Technical Module

We have discussed the design of the technical module of OLAP for our BI course. This section describes the delivery of this technical module to our students. Our BI course is an IS elective course offered for all business majors in the school of business at one of the authors' universities. The prerequisite for taking the course is an introductory IS course, which in turn has its two prerequisites of a computer literacy course and a business statistics course. The course includes both non-technical and technical modules. The main topic of the technical module is OLAP. The contact hours for the OLAP part are about one fifth of the course (nine out of forty five contact hours). We have created and used a teaching note to deliver this module that is consistent with the approach described above. Next, we explain the way we used to teach the technical module and the feedback we have received from students.

Delivery Method: Technical Assignment

We used a technical assignment for teaching and learning OLAP for the BI course. For students, the assignment was an OLAP competition. The assignment for the OLAP component included six steps, as briefly described below.

Step 1: Preparation – Each student received the teaching note of the technical module along with a small sample data cube resident in a Microsoft Access database file. The data cube consists of sales data and includes the dimensions of branch, product, and time period, as shown in the previous sections of this article. Students were asked to practice the four elemental OLAP techniques as briefly described in the fourth section by following the teaching note.

Step 2: Data acquisition – Each student was asked to use the `Northwind Traders` database, a companion sample database in Microsoft Access, for this assignment. The `Northwind Traders` database contains a reasonably large dataset for the assignment and is commonly available. Each student was asked to review all tables and the existing data cubes in the query objects category of the database and to select one or more existing data cubes from the `Northwind Traders` database for OLAP.

Step 3: OLAP strategy initiation – Each student was asked to act as the new CEO of `Northwind Traders`, to overview the data set, to understand the nature of the business of this company based on her/his assumptions, and then to generate ideas of OLAP strategy for the company. Each student was asked to articulate her/his OLAP strategy by following the guidelines discussed in the second section.

Step 4: Creating new data cubes – This step was optional, because the `Northwind Traders` Access database has generated many queries (data cubes) already. However, a student could create new data cubes in Access by using her/his own queries. This optional step encouraged students to develop diverse OLAP strategies.

Step 5: Performing OLAP using Excel – Each student was asked to use Excel to connect the `Northwind Traders` database, to create OLAP cubes in the form of pivot table in Excel, and to perform OLAP by applying and extending the knowledge and skills acquired through Step 1. Each student was expected to find *interesting*, *meaningful*, and *significant* facts to implement the OLAP strategy, and is encouraged to conduct OLAP by integrating multiple elemental OLAP techniques. The minimum requirements were at least one OLAP result for each of the four elemental OLAP techniques discussed in Section 4, but the quality of OLAP practice was assessed by the competitive comparison of all assignments.

Step 6: Presentation and competition – Each student was required to write a report for the assignment to summarize what she/he had learned from this assignment for OLAP and BI in general, and was required to present the OLAP strategies and findings for a class competition. The best OLAP strategies and the most interesting OLAP results were recognized through class discussions.

Feedback from students

All students completed the OLAP assignment meeting the requirements specified. Unsurprisingly, the OLAP results were quite diverse since they created their own OLAP strategies. We requested students to anonymously complete a short questionnaire. The responses from 25 students are summarized in Table 1.

Table 1: Summary of Students' Feedback from Sample Classes	
Questions	**Percentage of Students Who Agree or Strongly Agree**
1. The concept of BI empowered by OLAP is important for business students	88%
2. The concept of BI delivered by OLAP meets your expectation of this course	92%
3. You believe that learning OLAP enhances your knowledge set, skill set, and integrated thinking ability	80%
4. The OLAP technique is relatively easy to learn	64%
5. The workload of the OLAP technical assignment is appropriate	80%
6. The OLAP teaching note is useful for the BI course	88%

We recognize that we have only a small sample, and thus this summary of students' feedback is preliminary. The business intelligence course is still in the trial stage in the IS curriculum and the enrollments of this course have not reached to the normal class size.

Conclusion

OLAP is an important BI tool, but there has been a lack of hands-on material of OLAP for business students in the existing textbooks and the literature. Through the design and teaching of the OLAP technical module for the BI course, we are convinced that this technical module has positive impacts on learning and teaching BI. Our preliminary observations are encouraging. Student evaluations have indicated their positive learning experiences and overall satisfaction with the OLAP technical module. By exercising the hands-on examples in the teaching note, students had no difficulty in learning the OLAP technical module within a short timeframe. The progressive nature of the technical assignment also accommodates differing levels of preparation for learning the OLAP technique and sets the stage for students to progress to advanced levels on their own. We conclude that the OLAP technical module is practicable and very useful for the BI course.

Our primary purpose writing this article was to share what we have learned and developed while incorporating an OLAP technical module in a non-technical BI class. We have designed and implemented a hands-on OLAP module that operates in the Microsoft Office computational environment, a commonly available platform. The module has identified and provided guidelines for giving instruction on the four elemental OLAP techniques typically applied in performing OLAP-supported analysis. We believe that the OLAP technical module described above helps to fill a gap in non-technical BI courses where the emphasis has largely been on analyzing business cases. The most compelling implication of this effort is the recognition that BI can be applied virtually everywhere. Our experience demonstrates the potentially positive effect of inclusion of a practical, technical module in BI courses designed to meet the needs of business majors. The above guidelines should be of value to IS instructors wishing to incorporate a practical technical element in their business-oriented BI courses.

Acknowledgement

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Deepening Learning through Learning-by-Inventing

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Executive Summary

It has been shown that deep approaches to learning, intrinsic motivation, and self-regulated learning have strong positive effects on learning. How those pedagogical theories can be integrated in computing curricula is, however, still lacking empirically grounded analyses. In a more general level, it has been widely acknowledged that in tertiary-level computing education there is a desperate need for more creativity and innovation-friendly instructional approaches.

While the use of, for example, problem-based instructional approaches into computing education is increasing, their penetration into computing pedagogy is still shallow. In many contexts of higher computing education, teaching still follows a fixed set of instructional lectures, a fixed set of short-term learning objectives, and a fixed set of predetermined take-home exercises, followed by a pen-and-paper exam. A typical way to teach software development in higher computing education is to utilize industry-standard project management principles in a project, which aims for efficient and risk-free production of software which meets the demands of a customer or a client. As an alternative to the typical conventions, this study investigated students' learning in a learning environment that explicitly focused on inventing and creativity. In other words, this study integrated, in a robotics-based programming class, a method of learning-by-inventing and studied its qualitative effects on students' learning through 144 interviews.

Five findings were related with learning theories: changes in students' problem management cycle, problem-rich learning environment, conceptions of the nature of computing, extension of deep and surface approaches to problem solving and management, and the use of robotics to facilitate deep learning strategies. Our analysis suggests that a combination of an open learning environment, robotics as the learning tool, and learning-by-inventing provides a conducive environment for deep learning strategies, intrinsic motivation, and self-regulated learning, which are prerequisite conditions for creativity and inventing.

Keywords: learning-by-inventing, robotics, learning strategies, creativity, intrinsic motivation, problem-based learning.

Editor: Peter Blakey

Introduction

There is a plethora of well-justified categorizations for learning objectives in higher education. One of those categorizations is based on the intended levels of understanding (Biggs, 1979). Learning objectives range from ones that are narrowly defined and easily measured—such as learning of factual knowledge and certain specific skills—to ones that are broadly defined and difficult to measure—such as adoption of a deep approach to learning, improvement of activating and self-regulatory learning skills, learning of reflection and self-reflection skills, and development of creativity (Entwistle, 2007).

While the use of, for example, problem-based instructional approaches into computing education is increasing, their penetration into computing pedagogy is still shallow (O'Grady, 2012), and a typical way to teach software development in higher computing education is to utilize industry-standard project management principles in a project, which aims for efficient and risk-free production of software that meets the demands of a customer or a client (Baker, Navarro, & van der Hoek, 2003).

The learning environment presented in this study was targeted towards undergraduate computer science students. The environment was designed from the viewpoint of creativity research, which states that creativity requires the simultaneous presence of three broad components: intrinsic motivation, a cognitive process of idea generation and idea evaluation, and domain relevant skills (Csikszentmihalyi, 1996). The learning environment aimed at supporting intrinsic motivation and facilitating a process of idea generation and evaluation. The idea generation and evaluation process was facilitated by new peer-to-peer and peer-to-teacher classroom interaction styles, and by granting students control over all aspects of their own learning, including setting their own learning objectives. The learning environment utilized LEGO®Mindstorms robots as a platform for students' work.

A practical description of the learning environment, as well as the teachers', researchers', and students' positive experiences have been reported previously (Apiola, Lattu, & Pasanen, 2012). This study extends the previous results on students' learning in this creativity-supporting learning environment by looking at students' learning more deeply. In this study, students' learning is investigated by analyzing multiple sources of data through classical theoretical constructs that involve the concepts of intrinsic motivation, creativity, and students' learning.

For example, whilst there is an impressive array of research (see Trigwell, Prosser, & Waterhouse, 1999) on deep approaches to learning—starting from the original distinction by Marton and Säljö (1976)—its embodiments in modern creativity-supporting collaborative learning environments, as well as its implications to the design of such novel learning environments, are not completely understood. It has been argued, for example, that the classic deep approach to learning may prove to be too restricted to conceptualize collaborative, problem-based learning, in the sense that it has an individualistic focus (Lonka, Olkinuora, & Mäkinen, 2004), and that in the future it might be necessary to have finer distinctions among deep approaches with a more or less individualistic focus (Entwistle & Entwistle, 2003). Support for deep approaches to learning is considered to be a key component of efficient learning in multiple contexts of education.

On the one hand, the lack of understanding of learning approaches and other related concepts in creativity-supporting learning environments and, on the other hand, the abundance of competing theories on learning approaches and motivation make the analysis and design of modern problem-based learning environments a daunting task. What is the significance of pedagogical ideas—such as intrinsic motivation, problem discovery, creative problem solving, and threshold concepts—in analyzing students' learning in modern learning environments, and how can they be easily adapted in the design of learning environments supportive of efficient learning approaches?

This study investigated students' learning approaches in an experimental course, where learning of advanced programming and other computing topics were taught to undergraduate students by providing an open learning environment supportive of intrinsic motivation, problem discovery, and creative problem solving, and by utilizing LEGO®Mindstorms robots as the central vehicle for learning (see Apiola et al., 2012). In that particular pedagogical setting, students bring their own ideas of problems into the learning environment. The environment is not designed for providing problems but for supporting problem discovery and problem solving. The aims of the learning environment design included support for intrinsic motivation, risk-taking, and deep processing of problems in contrast to producing error-free textbook solutions.

The aims of this research study were to describe students' approaches to learning in this specific learning environment of computing education and to analyze those findings through a number of central theories of learning. In previous research, learning approaches have been frequently connected with conceptions of learning, motivation, and students' learning orientations, and thus, the research data was analyzed from these viewpoints, too. The central questions that guided this study were the following: 1) "Which kinds of learning approaches do students adopt in a creativity-supporting learning environment?", and 2) "Which factors of the learning environment support, and which undermine specific choices between learning approaches?"

Learning Theories

SAL (Students' Approaches to Learning), and SRL (Self-Regulated Learning) are two dominant research tracks on student learning (Lonka et al., 2004). SRL is based on ideas from North American research, while SAL is based on European research (Lonka et al., 2004). The distinction between deep and surface approaches to learning belongs to the SAL track, it was first presented in the mid-1970s (Marton & Säljö, 1976), and it has since been followed by a broad range of research. The SAL models have been criticized for oversimplifying learning, while the SRL models have been criticized for being too complicated to be of practical value for educators or educational researchers (Biggs, 2001).

Students' Approaches to Learning (SAL)

The deep approach to learning can be described as a knowledge-transforming approach, while the surface approach can be described as an information-reproducing approach. It has been shown that deep approaches to learning produce clearly better outcomes than surface approaches do (Marton & Säljö, 1976). The same student may adopt different learning approaches in different learning tasks (Richardson, 2005) and may switch between approaches also within one study task (Laurillard, 2005).

A student's approach to studying (deep versus surface approach learning) is formed in an interaction process with the learning environment (Marton & Säljö, 1976). It has been shown that a student's approach to learning is influenced by the student's general conception of learning (Marton, 2005; Marton, Beaty, & Dall'Alba, 1993; Van Rossum & Schenk, 1984), the student's conception of the specific learning task, and the student's conception of what is required of him or her (Marton & Säljö, 1976). It has also been shown that intrinsic motivation generated by a non-demanding and supportive environment is related to deep processing, while extrinsic motivation generated by increased ego-involvement and threat to self-esteem is related to surface processing (Fransson, 1977). Deep and surface approaches to learning have been corroborated by a number of studies (Marton, 2005) and confirmed in many topics of study, such as in problem solving and engineering (Laurillard, 2005).

This study analyzed students' approaches to learning through students' conceptions of four things: learning in general, the specific learning tasks they were given, what is required of them, and openness of their learning environment.

Self-Regulated Learning (SRL)

A conceptual framework of self-regulated learning describes self-regulation in learning through four dimensions: cognition, motivation/affect, behavior, and context (Pintrich, 2004). According to the SRL framework, self-regulation in each of these dimensions follows a temporal sequence of planning and goal setting, monitoring, control, and reaction and reflection. Although the phases are described as temporally ordered, there is no strong evidence of the order, and different phases can occur simultaneously and dynamically; for example, goals and plans can be updated based on feedback from control processes (Pintrich, 2004).

Regulation of cognition represents activities and strategies of students for planning, monitoring, and regulating their cognition (Pintrich, 2004). Planning activities include setting specific cognitive goals and activating prior cognitive and metacognitive knowledge. Cognitive monitoring and control include activities to adapt and change cognition, including memory, learning, reasoning, problem-solving, and thinking strategies. *Regulation of motivation* includes regulation of beliefs, self-efficacy, perceptions of task difficulty, and task value beliefs, and the utilization of different coping strategies to deal with negative affects such as fear and anxiety. *Regulation of behavior* includes planning and management of time and effort; including making schedules and allocating time, help-seeking behavior, and capability to control effort and persistence in low-value, boring tasks. *Regulation of context* refers to efforts to control or regulate tasks and the context of the learning environment. Regulation of context is often restricted by the learning environment. However, in some student-centered classrooms students are encouraged to assume more control, for example, by designing their own learning tasks (Pintrich, 2004). In this study the SRL framework was operationalized by looking at students' reports on coping strategies, metacognitive knowledge, positive and negative affects, and time and effort regulation.

Intrinsic and Extrinsic Motivation

It has been argued that deep learning requires intrinsic motivation (Fransson, 1977; Marton, 2005), which is a type of motivation where a learner performs activities because he or she considers those activities to be interesting (Amabile, 1987; Ryan & Deci, 2000a, 2000b). On the contrary, an extrinsically motivated learner performs activities primarily due to external rewards or other goals extrinsic to the learning activity itself. Under test conditions, tasks which increased ego-involvement and which were perceived as threatening to self-esteem generated extrinsic motivation, which, in turn, resulted in surface approaches to learning. By contrast, a supportive and non-demanding learning environment was found to be intrinsically motivating and supportive of deep approaches to learning (Fransson, 1977).

Extrinsic rewards, such as positive evaluations or other rewards prior to performance, seem to create extrinsic motivation (Amabile, 1987; Amabile & Collins, 1999). On the other hand, if a task is constrained or controlled, it results in reduced autonomy and, thus, reduced intrinsic motivation (Amabile & Collins, 1999). The perceived level of autonomy and freedom are related to higher levels of intrinsic motivation, where, for example, competition for prizes for "best" outputs restricts intrinsic motivation and creativity (Amabile & Collins, 1999). The self-determination theory (SDT, see: Ryan & Deci, 2000a, 2000b) argues that intrinsic motivation can be supported by supporting its three forming factors: autonomy, competence, and relatedness. This study operationalized the SDT concepts by looking at students' reports on their level of autonomy, their feelings of competence, and their reports on collaborational (relatedness) aspects of their study work.

Conceptions of Learning and Intellectual Development

Research on conceptions of learning originated from the assumption that a student's perception of a learning task reflects his or her past experiences of similar situations, and thus mirrors the differences in a preconceived idea about what it takes to learn (Marton, 2005). Six qualitatively different conceptions of learning have been identified (Marton et al., 1993). Learning can be seen as increasing the quantity of information, as memorizing, as acquisition of facts and methods, as abstraction of meaning, as an interpretive process aimed at understanding reality, and as changing as a person (Marton et al., 1993). Similar conceptions have been confirmed by a number of research studies worldwide (Richardson, 1999).

Educational researchers have proposed various 'hierarchies' of learning (e.g., Anderson et al., 2001; Bloom, Englehart, Furst, Hill, & Krathwohl, 1956). It has been argued, although not well studied by longitudinal studies, that different conceptions of learning may represent a developmental hierarchy. In the research literature that argument has been supported by comments of informants who mentioned a process of transition between different conceptions (Marton, 2005). The argument is also supported by the similarity between conceptions of learning and Perry's (1970) model of students' intellectual development, which was based on a longitudinal study. Another study found a strong correlation between students' conceptions of learning and students' approaches to learning (Van Rossum & Schenk, 1984).

In addition to students' general conception of learning, research studies have confirmed that situation-specific conception about learning affects students' approaches to learning (Marton & Säljö, 1976). Those studies have yielded fairly clear-cut results indicating that the type of testing affects students' approach to learning, which is often called the "backwash effect" (Marton & Säljö, 1976; Biggs & Tang, 2011). Students adopt an approach based on their expectations of how they will be tested (Marton & Säljö, 1976). In the context of problem solving, students who concentrated more on what is expected of them were more likely to adopt surface approaches to learning (Laurillard, 2005). This study analyzed students' conceptions of intellectual development through the six conceptions of learning described by Marton et al. (1993), as well as through their notions of the backwash effect (students focus on what they think they will be tested on).

Learning Orientations

If a student has a general tendency to behave in a certain manner (such as adopting a deep or surface approach), that tendency may be viewed as a general property of a learner. Such tendencies related to learning are theorized as learning orientations, motivational orientations, or sometimes as learning styles (Lonka et al., 2004). Orientations may provide explanations for why certain students regard certain types of courses (for instance, practical courses) as the most relevant. Orientations as indicators of the basic meaning of studies essentially influence students' study goals and the way they plan, organize, and approach their studies and different learning tasks (Lonka et al., 2004).

One study categorized students' general orientations towards studying into three dimensions: utilizing, internalizing, and achieving (Biggs, 1979). The utilizing orientation resonates with surface approaches to learning, and it is characterized by extrinsic motivation in terms of avoiding failure, minimum effort, and syllabus-boundedness. The internalizing orientation resonates with deep approaches to learning, and it is intrinsically motivated and syllabus-free (student studies beyond the requirements and beyond the topic). The achieving orientation revolves around winning, and it utilizes a systematic approach for gaining highest possible grades using both deep and surface approaches, whenever appropriate (Biggs, 1979). In one study (Ylijoki, 2000), one main disciplinary "tribe" was identified within computer science students. That "tribe" was described as professionally or industrially oriented students who emphasize hard expertise and respect for pragmatic skills. That orientation was seen to be influenced by an institutional moral order and culture (Ylijoki, 2000). This study looked at students' learning orientations through students' reports on their failure-avoidance, adherence to syllabus, amount of effort, and emphasis of achievement.

Table 1 summarizes the theoretical constructs introduced above through which the research data was viewed.

SAL	Learning in general Specific learning tasks What is required of self Openness of the LE	**SRL**	Coping strategies Metacognitive knowledge Positive and negative affect Time and effort regulation
Intrinsic motivation	Level of autonomy Level of competence Reports of collaborational aspects	**Conceptions of Learning**	Six conceptions described in (Marton et al., 1993) Notions of backwash effect
Orientations	Failure avoidance Adherence to syllabus Amount of Effort Emphasis on achievement		

Table 1: Theoretical constructs for analyzing the interview data

Learning-by-Inventing (LBI) Environment

The development of the Learning-by-Inventing (LBI) Environment started from a vision of a learning environment for master's level students of computer science, where students, motivated by topics and projects of their own interest, could advance their studies by freely engaging in their own learning by working with various platforms, mobile phones, game consoles, gadgets, and robotics kits of their preferred choice. The vision included promotion of creativity, motivation, inventing, and deep learning through supporting a sense of freedom from restrictions, combined with hard work, fun, play, idea generation, and exploration.

The LBI environment was designed to support creativity, inventing (Csikszentmihalyi, 1996; Sternberg & Lubart, 1999), and deep learning (Marton & Säljö, 1976). Support of creativity involved the simultaneous overlap of three broad components: certain kinds of cognitive processes (persistent process of idea generation and evaluation (Jackson & Shaw, 2006) and deep learning (Marton & Säljö, 1976)), intrinsic motivation (Amabile, 1987; Ryan & Deci, 2000a, 2000b, 2001), and domain relevant skills (Amabile, 1983; Csikszentmihalyi, 1996). Constructionism is a support theory for working with LEGO®Mindstorms (Papert & Harel, 1991). Thus, LBI was designed to offer maximal support for the components of intrinsic motivation (competence, autonomy, relatedness), domain-relevant skills of creativity, creative processes (persistent process involving idea generation and evaluation), and constructionism (Apiola et al., 2012).

In practice, in LBI there was no teaching in the traditional sense, but sessions were arranged for discussing problems brought in by the students, for presentations and discussion of students' work, and for idea generation by utilizing a combination of different creativity methods, plays, and open workshops. For example, in the 3+ method (Lavonen & Meisalo, 2009), students were divided into groups and set in circles, where everyone in turn presented an idea regarding their project. The next student then had to present three positive things about that idea and after that give critique in a positive form. In other experiments, students prepared all their ideas and possible solutions in posters, which were in turn presented and explored by students of other groups. The leading idea behind all sessions was to create a creativity-enhancing, psychologically safe environment for generation and evaluation of ideas regarding the project work.

In LBI students were given maximum autonomy in all phases of their project work, without controlling evaluations. Students were not presented with topics to choose from, but instead they were encouraged and supported to come up with project ideas that they were interested in. This means that students could participate in setting their own learning objectives, learning tasks, and other parameters of the learning environment. The environment was designed to support risk-taking and deep processing of problems in contrast to error-free textbook solutions. The domain-relevant skills could be controlled by allowing only skilled students to enter the course. Table 2 presents the implementation of the LBI approach with six course sessions. (For a more thorough description of the LBI, see Apiola et al., 2012).

#	**Short description**
1.	Information and instructions. Distribution of robotics kits.
2.	Short lecture on creativity methods. Divide students into groups. Ideation exercises with the 3+ (Lavonen & Meisalo, 2009) method.
3.	Divide students into groups. Continue on creative working methods. Prepare posters. Use open space workshop (Harrison, 2008).
4.	Generate ideas using creativity methods in one large group. Discuss the phase and ideas of each groups project. Use open space workshop (Harrison, 2008).
5.	Generate ideas using creativity methods in one large group. Discuss the phase and ideas of each groups project. Use open space workshop (Harrison, 2008).
6.	Final demonstrations. Every group presents their final project.

Table 2: Example Learning Sessions in LBI (Apiola et al., 2012)

LBI has similarities to pedagogical approaches such as Problem Based Learning (PBL), Project Based Learning, and Progressive Inquiry. Problem Based Learning emerged from medical education and it offers a widely used model for learning by solving real-world problems (Hmelo-Silver, 2004; Jonassen, 2000). Progressive Inquiry implements scientists' methods to learning (Hakkarainen, 2003), while Project Based Learning unifies these two (Barron et al., 1998) and is applied in science disciplines where learning goals include research methods. The common denominator between these approaches is the changed role of the teacher from an instructor to a facilitator. The approaches also use realistic, open-ended cases and project goals, and stress collaboration between students.

In LBI, creative problem solving was emphasized at the cost of realistic open-ended cases and project goals. Instead of giving rigorous models to minimize risks or failures (such as the procedures of TRIZ (Fulbright, 2011; Tesheng, 2010)), in LBI students were encouraged to take risks and try something new for them. In LBI, students also set their own tasks and discovered their own problems instead of solving problems that teachers give to them. LBI did not encourage only certain types of problems (such as "realistic," or "pragmatic," or "real-world" problems), but instead welcomed all possible problems related to computer science, based on students' own preferences. The notion of *theory Y climate* assumes that students learn best if they are given freedom and room to use their own judgment (Biggs & Tang, 2011, pp. 39-45; McGregor, 1960). LBI, PBL, and other student-centered pedagogies are well aligned with the *theory Y climate*.

Methodology

This study aimed at exploring students' approaches to learning in a new type of a technology-rich creativity-supporting environment at the Department of Computer Science of the University of Helsinki. The theoretical lens for the study was combined from five complementary accounts of learning. The focus of this study was one course, given twice. One of the challenges was that in this study the context of research and the phenomenon itself (learning outcomes and learning environment) were irrevocably intertwined. Those characteristics led this study to be designed as a case study. The methodology literature advocates the use of the case study strategy when the aim is in-depth exploration of, e.g., an educational program (Creswell, 2009, p. 13), when the meta-question is "what can be learned from a single case?" (cf. Randolph, 2008, p. 53), and "when the boundaries between phenomenon and context are not clearly evident" (Yin, 2003, p. 13). Furthermore, the case study strategy is very well suited for education research: standard literature on the case study strategy commonly uses educational programs as an example (Stake, 1995, ch.10).

Of the various accounts of the case study strategy, this study adopted the procedures described by Creswell (2007, pp. 74–75). The first step of Creswell's procedure—establishing the appropriateness of the case study strategy—was concluded (see above). Second, the case was bounded to a single, focused case with a limited longitudinal dimension. The third step in Creswell's procedure is concerned with data collection. Data collection in case studies is strongly linked to the aims and objectives of research, while methodology literature commonly encourages participant observation and interviews (Richards & Morse, 2013, p. 77). Furthermore, it is proposed that several types of data collection should be employed, giving multiple perspectives to the case (Creswell, 2007; Yin, 2003). Therefore, this study used three different data collection methods to collect three sets of data: semi-structured student interviews (data set A), observation notes made by the researchers during and after each learning session (data set B), and students' study transcripts (data set C).

Sampling for interview data was a comprehensive sample, and it consisted of 72 initial interviews and 72 concluding interviews. All dropped-out students were reached for the concluding interviews, too. The interviews were semi-structured, and in the initial interviews students were asked to broadly describe their studies, including their personal interests. In the concluding interviews students were asked to describe, in detail, their learning process throughout the course. The interview protocol was tested with two randomly selected computer science students before the actual interviews. Interviews were tape-recorded and transcribed, and for the purposes of this article, quotes were translated to English by the authors.

The fourth step in Creswell's case study procedure is concerned with data analysis (Creswell, 2007, p. 75). As the aims of this study are exploratory and as answering the research questions requires rich descriptions, qualitative holistic analysis strategy (Creswell, 2007) was employed. Following the guidelines described by Stake (1995), we started with relatively uncontested data, looking for the theoretical constructs described in the Learning Theories section of this article. For example, if a student said that he/she tried to anticipate what constitutes "good performance" in the final grading, we marked that down as an instance of the backwash effect. Data saturation point was met roughly halfway the interview data after which no new theoretical constructs were encountered. However, as some theoretical constructs described in the Learning Theories section were not encountered at all, the full data set was analyzed. A number of phenomena outside the theoretical constructs were also identified: those are described in the following section. The same procedure was done on data set B (observation notes). Data set C (transcripts) was analyzed by looking at students' phase of studies, grade point averages (GPA), and course preferences (previous courses taken).

At the second level of analysis, the various instances of each theoretical construct and newly identified phenomenon were analyzed for contextual similarities and closeness to other theoretical constructs. That is, when we encountered variations of, for instance, backwash effect (see the Conceptions of Learning and Intellectual Development section of this article) in the interview data, we compared them with other interviews where backwash effect was found, with our observation notes, and with study transcripts. We looked at what other theoretical concepts and similarities those interviews, notes, and transcripts shared, as well as in which aspects they differed and conflicted with each other. However, the output of qualitative analysis is not statistical descriptions but rich descriptions. In this study those descriptions link the data with theoretical constructs. Those descriptions are outlined in the following section.

The final step in Creswell's procedure, the interpretive phase, looks at the meanings found in data. We connected our findings with the theoretical literature, proposed answers to our research questions, related our findings with other research studies on technology-rich learning environments, and constructed a number of lessons-learned from this case.

Results

Most theoretical constructs described in the section "Learning Theories" of this article manifested in various, rich forms in the interviews and observation notes. The next section below discusses students' disciplinary views, intrinsic and extrinsic motivation, and their theoretical and practical orientations. The section following that discusses students' reports on deep and surface approaches to learning in relation to their problem-solving strategies. That section also relates students' problem management approaches with their concepts of self-regulation. The last section below discusses students' conceptions of learning in the LBI context of learning.

Student Population and Example End Products

The course that this study evaluated was given twice. The rates of enrolled, active, and passed students at the first round was 36 enrolled, 25 active, and 18 passed; for the second round the rates were and 36 enrolled, 28 active, and 20 passed. A total of 38 students completed the course, with a total of 34 students dropping out. The dropout rate (47%) is normal in this context, where each semester students enroll in many different courses and complete some, but not all, of those courses. The attendees in the first round ranged from first-year students to postgraduate students with an average of 4.2 years of study. The population in the second round ranged from second year students to a sixteenth year student (average 5.6 years of study). The average ages were 25.8 for the first round, and 23.0 for the second round (see Table 3).

	Course 1	Course 2
Enrolled in the course	36	36
Active in the course	25	28
Passed the course	18	20
Average age	25.8	23.0
Average year of studies	4.2	5.6

Table 3: Course statistics for the first and second iteration of the course

Figure 1: Example Student Projects

Figure 1 shows examples of the students' work. The robot in the upper left corner is a drawer, in the second picture students are playing with various implementations of robot cars, which are remote-controlled by mobile phones and laptop computers. The third robot makes observations about the surrounding world. On the second row, there is a checkers-playing robot, a tic-tac-toe-playing robot, and a robot for simulating the work of sorting algorithms: the robot sorts the balls according to their color. There were a great number of different kinds of other projects too. The students' work was not graded (only pass/fail), as evaluation has been shown to restrict intrinsic motivation and creativity (Amabile, 1987).

Study Orientations (General)

The first broad theme that arose from the interview data was students' topic orientations among the various computing topics. Concerning their current studies and plans, students' answers indicated orientations towards three main categories: theoretical and scientific topics (such as algorithms, mathematics, physics, and theory of computing), pragmatic topics (such as software engineering and interaction design), and applied topics with interest towards arts, humanities, and social sciences. The categories were not distinct, and many students were unsure about their orientation and were enrolled in different courses in order to find topics of their liking. Some students had a clear view of their orientation, while some students showed interest towards topics across the three categories.

Interviews revealed a combination of extrinsic and intrinsic motivations. Most students reported an extrinsic motivational component in their studies, such as growing as a professional and obtaining qualifications for the labor market. The intrinsic component involved interest in the actual study topics and working on one's own extra-curricular projects. Students' motivational orientations were typically combinations of those two continua. The following paragraphs describe the most common combinations in the data.

The *pragmatically oriented, extrinsically motivated* student focused on hands-on engineering topics, often had high extrinsic motivation for gaining a formal qualification, and had low intrinsic motivation for studies: *"Well, I finished my Bachelor's studies in December and now I'm desperately trying to get a M.Sc.* […] *Not likely to happen* […] *These studies are kind of basic knowledge like data structures and software processes and some weird methodologies* [...] *Now when I* *leave and check out some jobs, I'm not gonna be able to really do anything—I just know some things* […] *so I hope that I get some work with that paper."*

The second common combination of students' orientations was the *pragmatically oriented, extrinsically and intrinsically* motivated student. Those students were often working in the IT industry, and although they were interested in the topics, they considered themselves to be too skilled to gain much from their studies. Those students were primarily interested in getting a degree by using their existing skill set. Many of them planned their curricular route and study approaches for minimum time to graduation.

The third common combination of orientations of students was the *theoretically or scientifically oriented student with mostly intrinsic motivation.* Those students had a high interest towards the subject matter, and most of them wished to gain research skills and develop themselves as researchers. Many of those students aimed at postgraduate studies: *"Of course I try to get the master's degree* […] *I sort of burn for, if I were good enough, for research career* […] *I think I have started to emphasize theory grinding and choose those courses* […] *I'm interested in their purity from practical baggage that comes with some unexplained bureaucracy-stuff unrelated to computer science"*. Every student with high interest in the theoretical tradition had high intrinsic motivation.

The fourth common combination of orientations of students was the *pragmatically oriented student with mostly intrinsic motivation*. Those students typically had high interest in the subject matter of their studies. They did projects of their own interests, and they explored and studied topics beyond the syllabus. In addition to high intrinsic motivation, those students also sometimes mentioned getting a job with a reasonable salary at some point of their life.

Approaches to problem solving and problem discovery

Characteristics of both deep and surface approaches to learning arose from the research data, which confirmed that both approaches were adopted in the LBI environment, too. Examples of statements that indicated deep approaches were numerous—for example*, "it was like, constantly learning through mistakes, you make a mistake and then have to correct it ...we had something ready, and then we started ...we built and wrote program codes and tried all variants on how it could work ...what was central in the whole process was, that it* [the right solutions and good ideas] *did not come easily ...all the time there was these open matters, which you had to think about and learn more ...for example in the last weekend from Thursday to Tuesday we started to tune the movements and motions of the robot to gain more accuracy, we thought and tested various different solutions, and finally combined with the light sensor we made measurements of the signal and tried some signal correction algorithms, but still could not gain data with enough precision.*" The emphasis on wanting to understand more, and the interest in learning more even if it takes a lot of time, strongly suggests a deep learning approach.

Examples of surface approaches to learning were also present. Students' responses that indicated surface approaches were of many kinds, but often in those responses students approached the problem with an intention to find a solution in the Internet or by asking their peers for help. In those responses students had no intention to understand and solve the problem themselves. For example, one student stated, *"With the practice I was irked at the stage when . . . how would you say . . . It was like, in principle, problems that you know someone has already solved. But you didn't, like, find anything helpful in the net. A way to solve it. Then I, well, asked for help, and, umm, I had a structural problem. I mean I couldn't get it* [the Lego structure] *like . . . attached to this base tightly"*.

In many cases situation-specific intrinsic motivation towards this course was obvious. In those cases students put enormous effort and time to the project, they used their own money to buy additional parts, had fun and explained flow-experiences, and made thorough investigations on connecting the device to other consoles and devices. In those cases all phases of project work were driven by intrinsic motivation. On the other hand, there were students whose orientations were mainly extrinsic: to gain study credits with the least work possible.

The cycle of work in the surface approach mainly involved applying students' previous knowledge to solve a previously identified problem. In the cases where that method failed, students attempted to find a working solution, using the Internet, for instance. The failing of that method often led to the generation of negative emotions, such as frustration. In the deep approach, when faced with a challenging problem, the student aimed at exploring other solutions, then moved on to making experiments, exploration, and prototyping—a learning process, which after persistence, eventually seemed to lead to a solution (which can either be knowledge which based on the project strategy may be updated, or a working solution to the original problem), and positive emotions, such as flow experiences.

Problem discovery and solving cycle

Because the LBI environment did not provide students problems to solve, students themselves had to find and select the problems they wanted to work on. Many students enjoyed the problem discovery process: *"It's learning in so many ways, that you don't only learn to build with Legos, but you come across problems that are just really impossible to predict and really impossible to foresee before you're standing in front of the problem. Those* [new problems] *just sneak on your way. Those are probably the biggest reward from this course."*

In the problem discovery process the challenges included, for example, how to circumscribe the problem, how to update the task's problem space, and how to continuously evaluate the suitability of one's problem solving strategy to the task. Self-regulatory skills played a very important role in overcoming these challenges. Another challenge concerned the difficulty of problems. The interviews indicated that it was hard for students to predict the amount of work that would be involved in their selected problems. Generally speaking, students' selected problems turned out to be more complex than they looked like on the first impression. On the one hand, this aspect of LBI facilitated deep learning, because it pushed most learners into the zone of proximal development (ZPD) (Vygotsky, 1978). On the other hand, too difficult problems were demotivating in those cases where students were not able to update their problem spaces accordingly. Choosing a suitable level of difficulty is a common challenge in learning environment design, but creativity researchers have suggested that too much challenge is better for learning than too little challenge is (Moneta & Csıkszentmihalyi, 1999).

Once each student had selected a problem to solve, students started to work on their problems. At that point they did the first choice between deep and surface learning approaches. Solving too easy problem does not require deep approaches to learning, and thus a proper amount of challenge is one important prerequisite.

Problem management approach

The interview data revealed a continuum of general project management processes employed by students. Those problem management approaches formed a continuum from serialistic to exploratory. Serialistic problem management approach attempted to treat the problem as a linear set of steps to be followed, somewhat similar to the waterfall model in software engineering: "*We thought of some ideas and then we decided what we are going to do. We thought a little bit about how we are going to develop the thing. After that we started building the robot. When the robot was ready we started coding it. We wanted something that would interact with its environment, but that turned out to be difficult. "*

In contrast, the exploratory problem management approach was a more organic, investigative, and iterative process. Students made prototypes, and they flexibly jumped back and forth between designs, prototypes, and models. They compared solutions and made experiments: *"...well I started* [the project] *from a concrete viewpoint: I took the LEGO bricks in my hand and started to build all sorts of different things… I thought that well, let's try this kind of thing: I will test this sensor and then I will test that other sensor and measure how much torque this motor has and things like that, I built small prototypes and wrote program codes for them. A program like this does something funny and then I realized that this is not at all what I want, and then you just build on it and at some point you have like one thousand lines of code and you think that this subject is not at all going to work and it is not what I want."*

Serialistic Approach	**Exploratory Approach**
Linear and iterative	Cyclic and free-moving
Serialistic	Holistic
Risk-averse	Open to risks
Industrial by nature	Hobbyist by nature
Closed-ended	Open-ended
Outcome-oriented	Experiment-oriented

Table 4: Characteristics of the Two Identified Problem Management Approaches

Table 4 presents some characteristics of the two problem management approaches identified in our interviews. Students' project management approaches probably influenced their problem discovery and selection, as well as their problem solving approach. As the LBI environment relied on open problem discovery, selection, and problem-solving, in this case the exploratory approach arguably worked better than the serialistic approach did. The two problem management approaches had clear parallels with deep and surface approaches to learning. Although the serialistic approach may be well suited for the industry, it does not seem to be well suited for learning, as it did not encourage one to enter the ZPD (Vygotsky, 1978). There again, the exploratory approach pushed the learner away from pre-determined models and solutions into developing of one's own problems, approaches, models, and solutions.

The data did not show students' reason for selecting problem management approaches. One reason might be related to the backwash effect: students chose approaches that they thought would be rewarded (and which other courses have rewarded). Otherwise, traces of backwash effect were not found in the data.

Conceptions of Learning

General conceptions of learning

Another broad theme arising from the interview data was students' conceptions of how a learning environment in computing should look. The working methods and new class interaction in the LBI were new to all students, who were used to traditional teaching arrangements. One student noted: *"I really had to take my time in getting used to the idea that this* [kind of course with these kind of working methods] *is really going to take place at our department* […] *I guess I am stuck with old views about how teaching should be arranged* […]".

One student who considered the openness and problem discovery process in the LBI environment to be a positive thing stated:

> *"*[…] *and then you are suddenly surrounded with such problems which seriously are just impossible to predict and impossible to see beforehand, before the situation is actually in front of you* […] *Those problems just somehow insidiously appear from somewhere, totally*

> *out of the blue* […] *those sudden problems are perhaps the biggest yield, which I gained from this course.* […] *That you see, that things are not what you thought them to be, but instead they are completely different even though you had imagined the whole process in advance, like: here is the problem* […] *but when you see it in front of you, you notice that you had planned it completely wrong, and then you think, how on Earth can this thing work this way. I have not seen anything like this in any other course of computer science before.* […]*"*

The quotes above suggest an expansion of the students' conception of a "proper" computer science learning environment. Students who considered openness to be a negative thing came up with various suggestions for improving the learning environment: fixed exercise sets, technical guidance, and strict deadlines. One student stated: *"Next time, I recommend that you provide those strict deadlines and phases of work in terms of planning, designing, coding and building, and testing. I also recommend that you provide clearer instructions for building the robots, topics to choose from, and also you should get the more advanced type of sensors with better accuracy".*

Situation-specific conceptions of learning

The next theme that arose from the data was concerned with situation-specific conceptions of learning. The LBI environment neither restricted the types of problems nor provided support for specific types of problems, but all kind of problems were welcome. Still, some students seemed to consider the course to be a hands-on, time-intensive engineering course. Indeed, many students chose engineering-oriented topics. But with some students, their situation-specific conception restricted the student from choosing a more theoretically oriented topic. Some theoretically oriented student dropped out because they did not consider that the course offered a platform for problems of their preference.

An example statement from a dropped-out theoretically oriented student: *"I am more interested in those things related to algorithms and such* […] *from this course, I was left with a feeling that even if you wanted to do some basic stuff, it will soon become complicated and require a high workload.* […] *So as development ideas, I suggest* […] *as for example in the Artificial Intelligence-course I liked, when the Roomba-robots were used and the project topic was restricted to write pattern recognition or image manipulation algorithms and such".*

In the first implementation of the LBI, we indeed observed that dropped out students (n=21) had a significantly higher GPA than students who completed the course (GPA 3.49 versus GPA 3.00) $p<.05$ [$F(1,38) = 5.312$, $p=.027$]. Higher GPA students in the course were also more theoretically/scientifically oriented towards studies. In the second implementation of the LBI the situation was the opposite, and the students who completed the course had a significantly higher GPA than students who dropped out (GPA 3.25 versus GPA 2.72), $p<.06$ [$F(1,33)=3.956$, $p=.055$]. This implies that students' situation-specific conception was different between the first and second rounds of implementation of the LBI. This hypothesis is supported by the increased amount of theoretically oriented project topics on the second round of LBI.

Discussion

This study asked two research questions: "Which kinds of learning approaches do students adopt in a creativity-supporting learning environment?" and "Which factors of the learning environment support, and which undermine specific choices between learning approaches?". This study found a number of interesting insights into students' approaches to learning with robotics as a learning tool, as well as into LBI as a pedagogical vehicle.

Firstly, students reported that the learning-by-inventing approach was able to relax their problem management cycle in a way that enabled students to deeply inquire into specific sub-problems as well as holistically engage in problem control. Secondly, students' reports suggested that the LBI approach was able to provide a learning environment that was rich with problems that could excite a variety of students with problems of their own liking. That approach stood in contrast to the previous practices where teacher gave either a list of homework problems to solve or a large assignment at the beginning of the semester.

Thirdly, students' reports imply that their intrinsic motivation was connected with their conceptions about the disciplinary nature of computing as well as their conceptions about effective learning environments. Fourthly, the free choice and management of problems had a number of consequences. Our initial concern was that in a very free environment students would choose problems that they already knew how to solve, which would lead to little or no learning. The concern did not materialize broadly, and if faced with a too difficult problem, students were able to quickly ease the problem parameters or find a different problem to work on. Thus, deep and surface approaches extended from learning to problem solving and problem management. Fifthly, the robots offered a powerful trigger for motivation, as well as a platform for a broad variety of problems that students presented.

In the broader scheme of things, the challenges of computing have, for the past 65 years, grown more complex every year. Computing continues to pervade other fields of life, which continues to diversify the problem types posed to computing professionals. At the same time, the complexity of problems with which computing professionals have to cope is growing. Our future professionals need to cope with a wide variety of problems and must be able to look at problems in innovative ways and from multiple perspectives. Educators in computing fields are already able to train students to work with basic types of problems—now we need to broaden our focus to creativity and real-life complexity. Pedagogical approaches, such as learning by doing, provide a good basis for training problem solving in computing education. The approach analyzed by this paper, an approach we call learning-by-inventing (LBI), extends learning-by-doing by facilitating learning of creativity and inventing through supporting new approaches to problem solving, and new approaches to learning in computer science.

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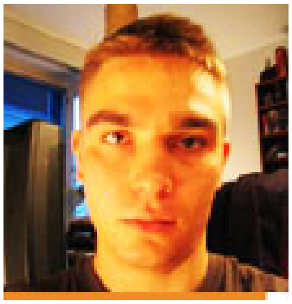

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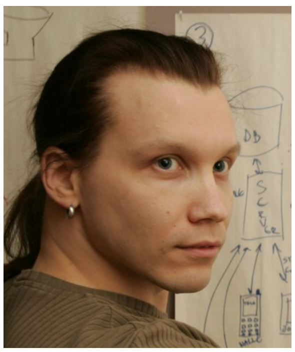

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The Wheels on the Bot go Round and Round: Robotics Curriculum in Pre-Kindergarten

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Executive Summary

This paper qualitatively examines the implementation of an intensive weeklong robotics curriculum in three Pre-Kindergarten classrooms (N=37) at an early childhood STEM (science, technology, engineering, and math) focused magnet school in the Harlem area of New York City. Children at the school spent one week participating in computer programming activities using a developmentally appropriate tangible programming language called CHERP, which is specifically designed to program a robot's behaviors. The children used CHERP to program "Robot Recyclers" that they constructed using parts from LEGO® Education WeDo™ Robotics Construction Sets. The Robot Recyclers were designed to help carry, push, and/or sort recyclable materials found in the classroom. Researchers were participant-observers in the robotics lessons over the course of curriculum implementation. Each lesson was taught by the researchers, with classroom teachers present in order to facilitate classroom management and assist with small group work. A combination of interviews, video, photographs, and classroom observations were used to document the students' experiences. Classroom teachers were also interviewed and asked to complete anonymous pre and post surveys. Results from this study provide preliminary evidence that Pre-Kindergarten children can design, build, and program a robot after just one week of concentrated robotics work. Additionally, results indicate that teachers were able to successfully integrate robotics work into their classrooms that included foundational math and literacy concepts while also engaging children in the arts. However, this study also highlights the difficulties and challenges that must be considered before implementing a robotics curriculum into a Pre-Kindergarten classroom, including opportunities for one-to-one adult assistance during building and programming activities.

Keywords: computer programming, Pre-Kindergarten, robotics, early childhood education, STEM

Introduction

As our world becomes increasingly digital, new initiatives and policies are in place with the goal of bringing STEM (science, technology, engineering, and math) education to the early grades (see Barron et. al., 2011; ISTE, 2007; National Association for the Education of Young Children & Fred

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Rogers Center 2012; U.S. Department of Education, 2010a, 2010b). While the majority of research on robotics and programming in education focuses on later schooling, teaching these subjects during foundational early childhood years can be an engaging and rewarding experience for young learners (Bers, 2008). Previous research suggests that children as young as four years old can build and program simple robotics projects (Bers, Ponte, Juelich, Viera, & Schenker,, 2002; Cejka, Rogers, & Portsmore, 2006; Perlman, 1976; Wyeth, 2008). Robotic manipulatives allow children to develop fine motor skills and hand-eye coordination while also engaging in collaboration and teamwork. Prior research demonstrates that kindergarteners can successfully learn powerful ideas of engineering, technology, and computer programming while also building their computational thinking skills (Bers, 2010; Kazakoff & Bers, 2012; Sullivan & Bers, 2012). However, very little research has been done on the use of robotics and computer programming in Pre-Kindergarten classrooms.

New York State, the location of the school where this pilot study took place, aims to align its curriculum with the Common Core Standards. The Common Core Standards are a single set of educational standards for Kindergarten through 12th grade that states voluntarily adopt. Currently, forty-five states have adopted the Common Core Standards. Within these standards for Pre-Kindergarten, there are several benchmarks for technology education that can be found in the New York State Pre-Kindergarten Foundation for the Common Core (NYSED, 2011). According to these standards, Pre-Kindergarten children should be able to do the following: 1) understand how technology affects them in daily life, and how it can be used to solve problems, 2) how to use computers for writing, drawing, and exploration, and 3) how to use technological tools independently (NYSED, 2011).

In light of these Common Core Standards, the purpose of this study is to qualitatively examine how an intensive robotics curriculum is implemented in three Pre-Kindergarten classrooms at a STEM-focused magnet school and describe how this curriculum was implemented in a developmentally appropriate way. The goal of this paper is to describe the feasibility of implementing a 10-hour robotics curriculum in Pre-Kindergarten by detailing the curriculum, the implementation procedures, the learning outcomes from students, and the thoughts of classroom teachers. This exploratory study adds to the budding research base regarding technology and engineering in early childhood education.

Developmental Considerations

Children in Pre-Kindergarten, according to Piagetian theory, are within the preoperational stage, characterized by learning about symbolic representation. Children learn through assimilation and accommodation. Assimilation is taking information in to fit ideas or knowledge structures that already exist. Accommodation is when children alter their understanding based on new information (Piaget, 1977; Siegler, 1998). Assimilation and accommodation work with each other as a child learns a new concept: in the case of this study, the concept of "robot" or "engineer".

Vygotsky (1978), building on Piaget's work, emphasized the social context of the child. One of Vygotsky's most well-known concepts, the zone of proximal development, describes how children can achieve goals with the help of teachers and peers, which they would not otherwise be able to achieve on their own. Vygotsky's theories around the influence of social context, particularly now with children's exposure to digital technologies, are influential when developing curriculum that aims to bridge real world and classroom experiences. In addition, opportunities for social interactions, collaboration, and scaffolding are planned directly into early childhood curriculum, such as the one used in this study.

Some contemporary research on STEM education in Pre-Kindergarten focuses on how technology may be used as a manipulative. For example, computer-mediated curriculum, like the Building Blocks curriculum for math, uses digital manipulatives, putting everyday problems on the screen for young children to solve (Clements, 2002). The curriculum used in the current study also uses on screen and physical manipulatives to aid children in solving their own contextualized challenges (e.g., making a robot recycle).

For young children who are in a developmental process of learning how to work with others, the design features of certain types of technology can promote social and pro-social development (Bers, 2012). Early work with technology and young children has shown that computers can serve as catalysts for social interaction in early childhood education classrooms (Clements, 1999) and that children have twice as many verbal interactions in front of the computer than when they are doing other activities, such as solving puzzles (Svensson, 2000). Children are also more likely to go to their peers for help when using the computer, even when an adult is present, thus increasing the amount of peer collaboration in the classroom (Wartella & Jennings, 2000).

Robotics in Pre-Kindergarten

Robotics was chosen as a domain for several reasons. As a tool, it can help make abstract ideas more concrete, as the child can directly view the impact of his or her programming commands on the robot's actions. Children who work with robotics are not sitting in front of a computer, but are engaged in developing fine motor skills while manipulating the robotic objects. They can move around the room, work on the floor or table, and act out, with their own bodies, the programming sequences the robots will follow. Robotics becomes the new early childhood manipulative of the 21st Century (Bers, 2008). New technologies, in general, and robotics, in particular, make different kinds of learning opportunities possible, including new ways to foster peer social interactions, and many opportunities for creativity, social, and cognitive development. Educational robotic kits are a new generation of learning manipulatives that also help children develop a stronger understanding of mathematical concepts such as number, size, and shape in much the same way that traditional materials like pattern blocks, beads, and balls do (Brosterman, 1997).

While there are a host of robotic kits and programming languages designed for older children (e.g., LEGO™ Mindstorms), in early elementary school there are a limited number of robotics tools available, and many focus on social interaction rather than on programming (e.g., Keepon, Tofu, Mocchi) (Kozima, Michalowski, & Nakagawa, 2009; Stiehl, Chang, Wistort, & Breazeal, 2009). For teaching young children to control the actions of robots, schools primarily use Bee-Bots and ProBots. Beebots and Probots are commercially available robotic toys developed by Terrapin Thinking Tools (http://www.terrapinlogo.com). The Beebot (a colorful robot designed to resemble a bee) contains keys that are used to enter up to 40 different commands. By using these commands, children can send the Bee-Bot forward, back, left, and right. Similarly, the Pro-Bot (a colorful robot that resembles a car) was developed by the same makers of the Bee-Bot and allows for more advanced control techniques and the use of sensors.

The development of these types of robotic toys for young children falls in line with research that has shown young children are able to understand robotic rules and create commands for robots to follow (Mioduser & Levy, 2010). As mentioned, research has demonstrated that children as young as four years old can build and program simple robots and that there are many benefits of integrating robotic technologies into the early childhood classroom in developmentally appropriate ways (Bers, 2008, 2010; Bers et. al., 2002; Kazakoff & Bers, 2012; Kazakoff, Sullivan, & Bers, 2013; Rogers & Portsmore, 2004). In addition to learning to program, Beebots and Probots specifically have been used to teach math concepts in preschool (Highfield, 2010).

Both from an economic and a developmental standpoint, educational interventions that begin in early childhood are associated with lower costs and longer-lasting effects than interventions that begin later in childhood (Cuhna & Heckman, 2007; Reynolds, Temple, Ou, Arteaga, & White, 2011). In addition, preliminary research suggests that children who are exposed to STEM curriculum and computer programming at an early age demonstrate fewer gender-based stereotypes regarding STEM careers (Metz, 2007; Steele, 1997) and fewer obstacles entering these fields (Madill et al., 2007; Markert, 1996).

Some aspects of engineering are very commonly seen in early childhood classrooms. For example, it is common to see young children using recycled materials or Lego bricks to build cities and bridges. However, what is unique to our human-made world today is the fusion of electronics with mechanical structures. Through robotics education, young children can become engineers by playing with gears, levers, motors, sensors, as well as storytellers by creating their own meaningful projects that react in response to their environment (Bers, 2008).

Robotics was chosen for this study because of the power of robotics as a tool that spans the science, technology, engineering, and math fields. Primarily, robotics encompasses the electronic aspects of engineering that is often missing in early childhood education.

Computer Programming in Early Childhood Education

One of the first programming languages for children, LOGO, was designed by Seymour Papert (1980) with the goal of helping children learn mathematics in a new way and enhance problem-solving skills. Continued research showed that mediated use of LOGO, the use of the programming language in context, with instruction by teachers and feedback on performance, with a goal of building transferable skills, actually demonstrated the most educational value (Siegler, 1998). Reviews of early studies, particularly using LOGO, have demonstrated using computers likely impacts young children's higher-order thinking skills, such as theory of mind, problem solving, self-monitoring, and metacognition (Clements, 2002).

Recent research and theories based on new programming environments support the argument that children's programming of animations, graphical models, games, and robots (with age-appropriate materials) allows them to learn and apply concepts such as abstraction, automation, analysis, decomposition, and iterative design (e.g., Lee et al., 2011; Mioduser & Levy 2010; Resnick, 2006; Resnick et. al., 2009).

When children program robots, they are engaged in sequencing the commands that comprise a robot's program (Kazakoff & Bers, 2012; Kazakoff et al., 2013). Sequencing is an important early childhood skill found in both curricular frameworks and, subsequently, in many learning assessments. Sequencing is a component of planning and involves putting objects or actions in the correct order (Zelazo, Carter, Reznick, & Frye, 1997). For example, retelling a story in a logical sequence, ordering numbers in the correct sequence, and understanding the sequence of a day's activities are all sequencing activities represented in curriculum frameworks for kindergarten through second grade in both language arts and mathematics (Engage NY, 2011; MA DOE, 2011a, 2011b). Sequencing, along with sorting, measurement, and pattern recognition are a child's mathematical building blocks; starting with these foundational skills, children begin to think of the world mathematically (Sarama & Clements, 2003). Prior research with the robotics and programming curriculum used in this study has shown repeated, significant improvements in sequencing skills for children in kindergarten classrooms (Kazakoff & Bers, 2012; Kazakoff et al., 2013).

Programming with CHERP

The programming software used in this study is called CHERP (Creative Hybrid Environment for Robotic Programming). CHERP is a hybrid tangible and graphical computer language designed with funding from the National Science Foundation to provide young children with an engaging and developmentally appropriate introduction to computer programming. CHERP allows children to create both physical/tangible and graphical/on-screen programs to control their robots (Bers & Horn, 2010). Children can create physical programs using interlocking wooden blocks or on-screen programs using the same icons that represent actions for a robot to perform (Figure 1). Informed by the spirit of puzzles, there is no such thing as a syntax error. With CHERP, the shape of the interlocking blocks and icons creates a physical syntax that prevents the creation of invalid programs. CHERP programs can be compiled in a matter of seconds with the press of a button.

Figure 1: CHERP Computer Programming Software

CHERP uses a collection of image-processing techniques to convert physical programs into digital instructions. Each block in the language is imprinted with a circular symbol called "TopCode" (http://users.eecs.northwestern.edu/~mhorn/topcodes). These codes allow the position, orientation, size, shape, and type of each statement to be quickly determined from a digital image. A standard webcam can be connected to a desktop or laptop computer to take a picture of the program, or a laptop's internal webcam can be used. A compiler converts the picture into digital code that is downloaded and transmitted to the WeDo™ robot through the LEGO® WeDo™ USB hub.

Robotics Curriculum in Early Childhood

The curriculum implemented during this study was designed according to the Positive Technological Development Framework (PTD). The PTD framework is an extension of the computer literacy and the technological fluency movements that have influenced the world of educational technology but adds psychosocial and ethical components to the cognitive ones (Bers, 2006, 2008, 2010, 2012). PTD takes into consideration the learning environment, pedagogical practices, as well as cultural values and rituals that mediate teaching and learning (Rogoff, 2003; Rogoff, Goodman, Turkanis & Bartlett, 2001). A curriculum designed following the PTD framework, such as the one presented in this paper, provides a learning experience in which children can use robotics as a medium to develop a sense of competence and confidence in their technological skills and their creativity in developing projects from idea to final implementation to sharing them with a community. Among the skills that the PTD framework fosters are social interaction skills such as communication, collaboration, and choices of conduct.

The robotics curriculum used in this study was integrated with a larger, exploratory unit on tools that the Pre-Kindergarten classes were already completing as part of their standard curriculum. The curriculum involved approximately 10 hours of work over the course of 5 days. Implementation of this study coincided with the school's "Robotics Week," an intensive school-wide experience where all classes are immersed in robotics, computer programming, and engineering for one week. During this time, the Pre-Kindergarten students in this study spent the week focused on designing, building, and programming robotic tools that can assist with the recycling process.

The Engineering Design Process

The Engineering Design process was a central aspect of the robotics curriculum implemented in this study. When working with young children and robotics, teachers may encounter problems scaffolding the child's problem-solving processes (Bers, 2008). Understanding and applying the

Engineering Design Process (Figure 2) is a useful tool for children to manage their frustrations and continue working on a given programming or building task without giving up (Bers, 2008). The Engineering Design Process is a cyclical process used by real-world engineers. Its steps include identifying a problem, looking for ideas, developing, testing and improving solutions, and sharing solutions with others. In the classroom, the Engineering Design Process places emphasis on continually changing and refining the child's work rather than achieving "the right answer" at the start. This idea of constantly testing and improving your work based on feedback and help from your peers lines up with the skills of communication and collaboration fostered by the PTD framework.

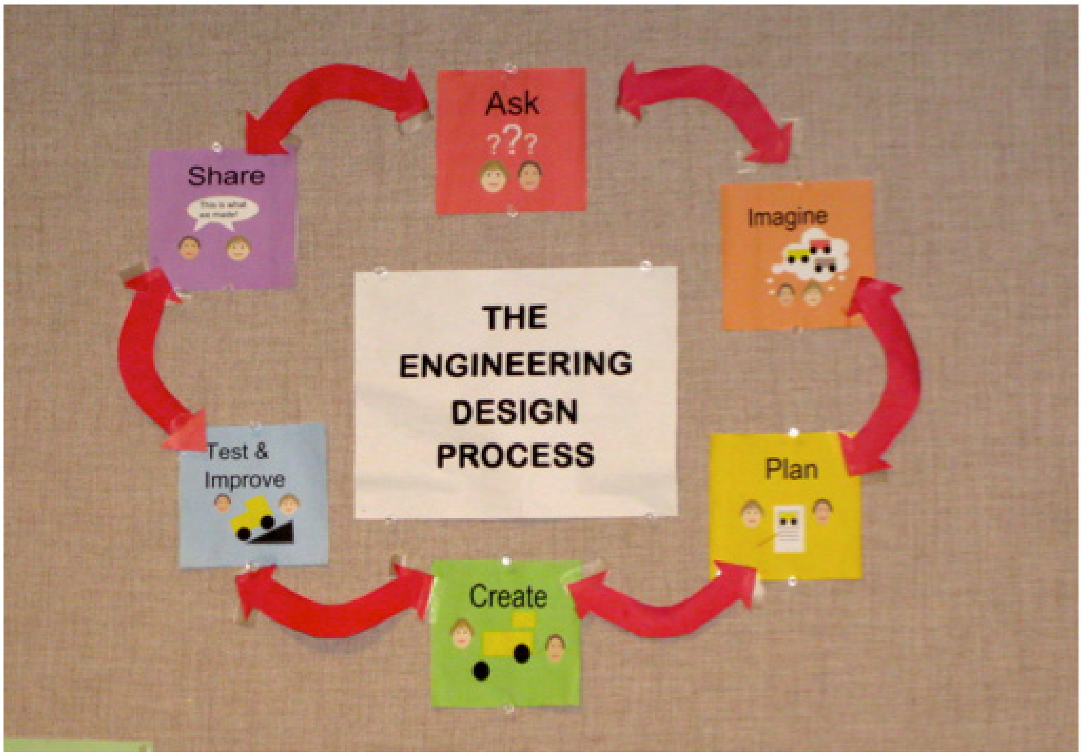

Figure 2: The Engineering Design Process

Robotics Hardware

The LEGO® Education WeDo™ *Robotics Construction Set* is a robotics kit that allows children to build LEGO® robots that feature working motors and sensors. The construction sets contain more than 150 elements including a motor, tilt sensor, motion sensor, a LEGO® USB hub, gears, and a variety of LEGO® bricks. Students also used LEGO® wheels (not included in the kit) to build their robots (Figure 3).

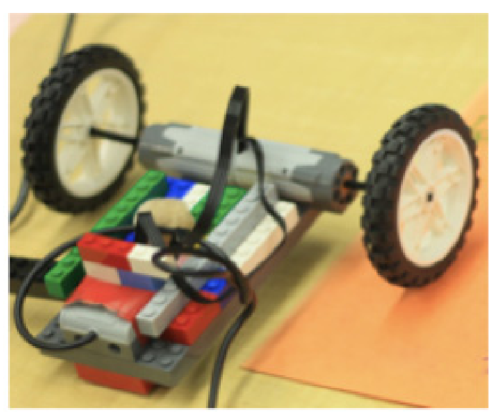

Figure 3: Child-Made LEGO® WeDO™ Robot

Once a robot is built, a tangible program can be uploaded to it by placing the program in the web camera's field of view and connecting the robot to the computer using the USB hub. The computer takes a photo to "see" the blocks, and then the program is visible on-screen and is sent to the robot. To upload from the graphical icons on-screen, children click and drag the programming icons together. Like the tangible blocks, they will only "snap together" when they are close enough and can make a logical sequence.

Method

Qualitative data collection measures were employed to examine the pilot implementation of an intensive robotics curriculum in three Pre-Kindergarten classrooms (N=37) at an early childhood STEM magnet school. In addition to studying the child participants, the three Pre-Kindergarten teachers from each of the participating classrooms also completed surveys reflecting on the experience.

Participants

Participants in this study were 37 Pre-Kindergarten students attending a public, early childhood magnet school in the Harlem area of New York City. These 37 students come from all three Pre-Kindergarten classrooms at the school. While all 55 enrolled Pre-Kindergarten students were invited to participate, these 37 children represent those that returned signed consent forms from their parents (67.3% consent rate). These students were identified by their parent/guardian as members of the following groups: 50% African American, 12.5% Hispanic, 6.3% Mixed Race, 3.1% Caucasian, and 3.1% West Indian. The remaining 25% of students were identified as either "other" or their parent/guardian chose not to answer. At the time of the study (near the end of the school year) all participating children were 5 years old. A fairly even number of male and female students participated (approximately 54% male and 46% female).

In addition to the children sampled, the three Pre-Kindergarten teachers from the school also participated in this study by completing pre and post surveys regarding their perception of student knowledge and mastery of concepts being taught. All teachers were female and had over 20 years of teaching experience (an average of 23.3 years).

Procedure

Researchers were participant-observers in robotics lessons over the course of a five-day introductory robotics curriculum being implemented at the school. Each lesson was taught by the researchers, with classroom teachers present in order to facilitate classroom management and assist with small group work. A combination of formal and informal interviews, video, photographs, and classroom observations were used to document the students' experiences. Classroom teachers were interviewed and asked to complete anonymous pre and post surveys. This paper will focus on presenting data from the interviews, questionnaires, and observations described below.

Interviews

Due to the busy public school environment and limited time available during curriculum implementation, researchers were not able to individually interview all 37 participating Pre-Kindergarten students. Subsets of approximately eight children were selected from each Pre-Kindergarten classroom by their teacher. This selection was based on the child's schedule and their willingness to participate. The selected students participated in formal interviews at the beginning and end of Robotics Week. Children were asked to describe their thoughts on the definition of the words "engineer" and "robot". The children were also asked if they were familiar with the Engineering Design Process (this was the main concept taught during the robotics week) and to list as many of the steps of the Engineering Design Process as they could.

Teacher Surveys

Each of the three Pre-Kindergarten classroom teachers completed an anonymous pre-survey before Robotics Week and an anonymous post-survey upon completion of the week addressing their conceptions of teaching and learning through robotics through a combination of Likert-scale and free-response questions. The post-survey specifically asked questions about how much they thought their students learned about robotics and computer programming. The post-survey also asked teachers to reflect on how well math and literacy were integrated into the robotics curriculum.

Classroom observations

During class sessions, the researchers conducted unstructured observations while implementing the robotics curriculum. Due to the researcher's dual role in the classroom (to observe as well as teach a curriculum) the unstructured approach was chosen over a structured or semi-structured approach in order to allow the researchers flexibility to divide their attention and deal with any classroom issues. Researchers paid particular attention to student behaviors, problem-solving strategies, social interactions, and their expression of ideas related to robotics, computer programming, and engineering. Additionally, researchers recorded notes on the robotics final projects created and programmed by the students. Observations were recorded in the form of written field notes during and after class sessions.

Robotics Program Overview

Curriculum

The robotics curriculum involved approximately 10 hours of intensive work over the course of 5 days (approximately 2 hours per day). Implementation of this curriculum coincided with the school's "Robotics Week," an intensive weeklong experience where all classes are immersed in robotics, computer programming, and engineering. Prior to this week, the Pre-Kindergarten students completed an introductory unit on tools. Throughout this unit, children became familiar with to concept of tools and investigated the use of common tools around the house, garden, and school. The robotics curriculum was designed to serve as the culmination to this unit on tools. Students spent the week focused on tools that can assist with the recycling process. Children designed these tools by engaging in the engineering design process, built them using the robotic kits, and programmed their behaviors using the programming language associated with the kit. After developing proficiency in several core areas of engineering, robotics, and computer programming during the first half of the week, children worked in small groups to build and program "Robot Recyclers" (Figure 4) to help carry, push, and/or sort recyclable materials found in the classroom, aligning with the state curriculum framework of "expresses an understanding of how technology affects them in daily life, and how it can be used to solve problems" (NYSED, 2011, p. 37). Robotics Week culminated in a school-wide Open House, to which parents, siblings, and students from a neighboring school were invited to attend. The Pre-Kindergarten students demonstrated their Robot Recyclers for this open house and also explained to guests what recycling is and how their robots can help.

Figure 4: Sample Robot Recycler

The core concepts covered during the unit were broken up into the following activities:

- **Activity 1: What is the Engineering Design Process & What are Engineers?**

  Students were introduced to what an engineer is and how to use the engineering design process (see "the Engineering Design Process Song" in the Appendix). Children learned about different types of engineers and played games that allowed them to identify structures designed and made by engineers (versus naturally occurring structures and living things). They used LEGO® and art materials – all non-robotic materials – to build a sturdy model of a real-world tool they had been studying. The powerful idea in Lesson 1 (building sturdily through use of the Engineering Design Process) is critical to the success of the children's robots in later lessons and was revisited throughout the week.

- **Activity 2: What is a Robot?**

  Students shared and learned ideas about what robots are. They were introduced to LEGO® WeDo™ robotics concepts (see "the Robot Parts Song" in the Appendix). Children built and tested their own robotic vehicles.

- **Activity 3: What is a Program?**

  Students learned about programming and were introduced to the various CHERP programming commands. Students programmed their robots to help push crumpled paper.

- **Culminating Project: Robot Recyclers**

  Students spent the remainder of the week (Wednesday-Friday) modifying their robots or building from scratch to create a "Robot Recycler". Students programmed these robots to perform a function related to recycling in the classroom (i.e., pushing, carrying, or sorting paper or other materials). Students were allowed to freely explore and test out sample programs with the end goal of having a functioning recycler by the end of the week.

In addition to these engineering concepts, each lesson integrated foundational concepts of math, literacy, and the arts. For example, throughout the week, children used Engineering Design Journals (Figure 5) to plan, design, and refine their robotic constructions and programs. By using these journals, children were engaged in a combination of writing, dictating, and drawing. Children also grappled with math concepts of shapes, counting, and sequencing while building and programming their robots. Students exercised their creativity in designing their robots and creating displays using arts, crafts, and recyclable materials. Finally, songs and music were used to teach the steps of the engineering design process (see Appendix.) and the parts of a robot. The song was also performed during the Open House.

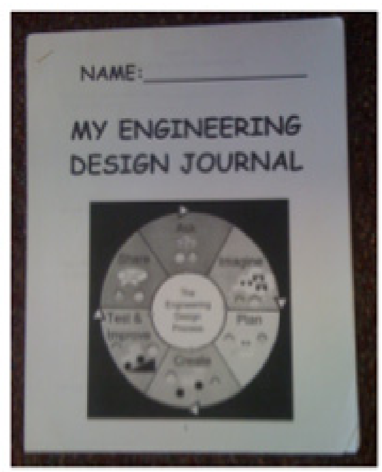

Figure 5: Engineering Design Journal

Results

Robotics Projects

Classroom observations and teacher interviews indicated that, by the end of the week, all groups of Pre-Kindergarten children (n=37 children, in 11 different groups) were able to create functioning robots for a final project and demonstrate these projects during an Open House at the end of the week. By the last day of robotics, all groups' robots contained two motors, wheels, and a LEGO® WeDo™ USB hub with wires correctly connected and securely attached. All robots also had a functional CHERP program by the end of the week. However, observations also indicated that each group received individualized help from an adult researcher (or their classroom teacher) during group building and programming time in order to ensure they had functional final projects.

Knowledge of Engineers

Classroom observations indicate that children had an increased understanding of what engineers do by the end of the week. Based on formal interviews with a subset of children (n=23) at the end of the week, nearly half (47.8%) described an engineer as someone who builds or designs things compared to only 32% at the beginning of the week. Some children were able to give detailed descriptions and provide examples of different objects made by engineers, while others simply said, "they build things". For example, one child responded, "Someone that builds something, like a robot, a car, an airplane, and a helicopter."

Prior to curriculum implementation, most children expressed they were only exposed to engineers as someone who drives a train. As one research assistant noted in their observations, when teachers attempted to introduce the concept of engineers, the children quickly became fixated on trains and it was initially difficult to expand their schema of an engineer.

Knowledge of the Engineering Design Process

In-class observations also showed children were able to identify the different steps of the Engineering Design Process, primarily when singing the Engineering Design Process song that was taught during the week (see Appendix). However, when formally interviewing a subset of children at the end of Robotics Week, only 3 (out of 23) were able to provide any of the steps. One student replied, "You ask a question and you imagine and you share and you test" while the other 2 students were able to provide all of the steps "Ask, Imagine, Plan, Create, Test & Improve, Share". The remaining 20 students typically answered that they could not remember or did not know.

Robotics and Programming Knowledge

In a post survey, the Pre-Kindergarten classroom teachers were asked to rate on a scale from 1-5 how much their students learned about robotics (1 being nothing and 5 being a significant amount). All three teachers gave a score of 4 or 5. On the same 1-5 scale, the teachers were also asked to rate how much their students learned about programming. Once again, all three teachers gave a score of 4 or 5.

During curriculum implementation, all students were able to complete their final robotics projects and program their robots to perform a recycling related task. All robotic parts (motor, wires, hub, and computer) were connected correctly and all final programs were syntactically correct and allowed for either forward or backward movement across the classroom floor. When it came to programming their robots, one researcher observed that incorporation of the tangible programming blocks added to the absorption of the programming process, by creating a visual dimension that helped the students grapple with abstract concepts.

For most of the groups, completing the final project required a significant amount of individualized teacher attention. While most students were generally engaged in freely exploring their robots (without direct help), when it came to working on the specific task of choosing instructions that would allow their robot to help push or carry recyclables, the participants had more difficulty staying focused and troubleshooting errors in their programs. It was observed that children were not able to go through the stages of the Engineering Design Process in order to refine and improve their projects without direct help from the teacher. Most students were happy with whatever actions their robot performed, whether or not it was what they planned or directly solving the assigned task of creating a robot capable of “recycling”.

Subsets of children were interviewed at the end of Robotics Week to understand their concept of robots. Responses to this question were varied between children. Four children were able to describe a robot as a machine. For example, one child responded that, “a robot is a machine that moves”. Four children described a robot as something that can move according to the CHERP programming instructions they learned. For example, one child responded that a robot “goes forward, backward, spin, turn, and stops”. Two children associated robots with their Robot Recyclers projects and answered that a robot helps with recycling. The remaining participants gave answers that did not fit with standard definitions or ideas of robots (i.e., “A robot is a Thomas train”).

Math and Literacy

Observational data from researchers as well as the Pre-Kindergarten classroom teachers indicate that the robotics week curriculum engaged participating students in math and literacy in a variety of ways. All three of the Pre-Kindergarten teachers cited the design journals as a successful tool for integrating and practicing foundational literacy concepts during robotics time. In a post-survey, one teacher explained, “The children used a combination of drawing and beginning writing to describe their experiences in their robotics journal.” Figure 6 is an example of how a Pre-Kindergarten child used a combination of drawing and early writing in their Engineering Design Journal to document the programming blocks needed to help their robot “recycle”

Figure 6: Sample Design Journal Page from a Pre-K Student

In the teacher post-surveys, two of the three Pre-K teachers described their observations of their class practicing foundational math skills during the robotics work. In a post-survey, one teacher wrote, “The children had to identify shapes (in pictures and structures), think logically (programming) and count (how many times did they want their robot to perform an action)”. Researchers’ field notes further describe observations of the regular inclusion of early math skills into the robotics lessons and that the robotics work stimulated students’ interest in math. Observations described the children as engaged in counting and estimating when determining how far they wanted their robot to travel. According to both researchers and teachers, the children enjoyed freely building with Legos and grappling with the shapes and sizes needed to meet the design requirements of the Robot Recycler.

Discussion

The results of this study provide support of prior research stating that young children can build and program simple robots and that there are many benefits of integrating robotic technologies into the early childhood classroom in developmentally appropriate ways (Bers, 2008, 2010; Bers et al, 2002; Rogers & Portsmore, 2004). Specifically, this study provides some evidence that Pre-Kindergarten children can design, build, and program a robot designed to perform a specific task (in this case, recycling). After just one week of intense robotics work, all the children in this study (with the help of teachers and researchers) were able to create functioning robots for a final project and demonstrate these projects at an Open House. In line with Vygotsky's (1978) work on scaffolding, the structured guidance of classroom teachers and researchers were pivotal to the students' learning and achievement of curricular goals. Finally, the results of this study also indicate that integrating robotics into the regular schedule of a Pre-Kindergarten classroom does not necessarily require teachers to take time away from other foundational content. Instead, robotics can be used as a tool to allow children to grapple with math concepts, practice early literacy skills, and engage in the arts.

However, this study also highlights the difficulties and challenges that must be taken into account before implementing a robotics curriculum into a Pre-Kindergarten classroom. As compared to previous work on robotics with Kindergarten and older students (i.e., Bers 2010), the Pre-Kindergarten children in this study covered fewer robotics and programming concepts and required a great deal of one-on-one help from adults. Research suggests that with new technologies and digital manipulatives, young children are capable of exploring concepts that were previously considered too advanced for them (Resnick et al., 1998). However, the results from this study suggest that for very young children, mastering these new concepts may require significant scaffolding and teacher attention. For example, in order for all groups in this study to have functioning robotics projects by the end of the week, each group required individualized assistance from a grown-up during all of the building and programming time. The students in this study had the benefit of their classroom teachers, researchers, and student volunteers in the classroom assisting with Robotics Week, resulting in an approximately 4:1 student to adult ratio, on average. In classes where fewer adults are present, modifications to the scope of the curriculum may be necessary. Additionally, this curriculum moved at a fast pace due to the time constraints of Robotics Week. In future iterations of the curriculum, it may be beneficial to expand the length of time devoted to each lesson, increase the amount of free-play time, and move more slowly through the curriculum in order to ensure that younger learners have a full understanding of each concept covered.

Introducing the concept of engineering to the Pre-Kindergarten children presented additional challenges that were not observed when implementing similar curriculum with older children. In particular, the teachers in this study expressed difficulty expanding the students' schema of what an engineer is (beyond someone who drives trains) and to foster an understanding of the Engineering Design Process and how it can be applied. Thus, expanding and strategically spacing the engineering lessons may be beneficial in the development of future curriculum for Pre-Kindergarten students. Despite these difficulties, in-class observations showed children were able to identify the different steps of the Engineering Design Process, primarily when singing and music was used. They were able, in some capacity, to apply engineering concepts to building of their own robotics creations, as evidenced by their finished products. Still, 20 students could not recall the Engineering Design Process in post-test interviews. This suggests that although the young children in this study may have had difficulty verbalizing and remembering engineering concepts, they were generally able to apply these ideas during the lessons themselves. Different assessment techniques may be needed for use with Pre-Kindergarten students in future iterations of this study.

The Robotics Week curriculum was designed to be aligned with the Common Core Standards (NYSED, 2011). Within these standards for Pre-Kindergarten, there are several benchmarks for technology education, including using computers for writing, drawing and exploration; as well as learning to use technological tools independently (NYSED, 2011). Preliminary results from this study, primarily the classroom observations and teacher surveys, demonstrate that a robotics and programming curriculum can be used to successfully address these Common Core standards. Children were engaged in freely exploring the robotics and programming materials and used these to create personally meaningful digital projects.

Limitations

The limitations of this study are those that come with working in classrooms. Several parents opted their children out of our research study and/or did not return permission slips despite several attempts at collection; therefore, we were unable to collect data on those children for this paper. As such, our sample size is not representative, by number, of three Pre-Kindergarten classrooms at the school. In addition, due to the nature of the work within the classroom, we were allotted limited time to carry out pre-test and post-test interviews, which were also interrupted by activities such as nap and snack. If a child was absent during pre- and/or post-testing time, he or she could not be included in analysis.

This study is comprised primarily of observational and interview data collected with the goal of exploring a group of Pre-Kindergarten students' and teachers' work with a robotics and computer programming curriculum that had been iteratively tested within kindergarten classrooms (Bers, 2010; Bers & Horn, 2010; Kazakoff & Bers, 2012). The study was intended to be exploratory and, therefore, was limited in the amount and type data collected. Since the classroom observations employed were unstructured (i.e., researchers were not coding for specific behaviors), the objectivity and generalizability of some findings may also be limited in this first pilot study.

Future Research

This study looked only at preliminary qualitative and quantitative findings on incorporating robotics technology into Pre-Kindergarten classrooms. Many of the suggestions received by the classroom teachers and researchers' field notes are currently being incorporated into new iterations of Pre-Kindergarten robotics curriculum. As a part of the Ready for Robotics project, early childhood teachers (Pre-Kindergarten through 2nd grade) from across the country will be systematically implementing a robotics curriculum and documenting this experience over the course of a whole school year. A combination of qualitative and quantitative assessments will be collected from both teachers and students in order to expand upon the findings presented here and inform best practices for incorporating robotics into Pre-Kindergarten classrooms.

Conclusion

Robotics offers young children and teachers a new and exciting way to tangibly interact with traditional early childhood curricular themes. This study demonstrates that it is possible to teach Pre-Kindergarten children to program a robot with developmentally appropriate tools, and, in the process, children may not only learn about technology and engineering, but also practice foundational math, literacy, and arts concepts. While there are many challenges to overcome when implementing robotics in a busy Pre-Kindergarten classroom, our work provides preliminary evidence that teaching young children about and through computer programming and robotics using developmentally appropriate tools may be a powerful tool for educating children across multiple domains.

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Appendix

Songs Used to Reinforce Engineering and Robotics Concepts

The Engineering Design Process Song

We ask and imagine,

We plan and create,

We test and improve,

And then we share!

The Robot Parts Song (to the tune of "Dry Bones")

The motor is connected to the, wire.

The wire is connected to the, hub.

The hub is connected to the, computer.

So, move, robot, move!

Biographies

Amanda Sullivan is a doctoral student working with the DevTech Research Group at the Eliot-Pearson Department of Child Development at Tufts University. She holds a B.A. in Psychology and an M.A. in Child Development. Amanda's research interests broadly examine the role of new technologies and media in the lives of children. Her current work focuses on best practices for integrating robotics and computer programming into early childhood education.

Elizabeth R. Kazakoff is a doctoral student working with the DevTech Research Group at the Eliot-Pearson Department of Child Development at Tufts University. She holds a B.S. and M.Ed. in psychology. Elizabeth's broad research interests focus on how new technologies impact early childhood development, especially interactive robotics and programming tools. Her dissertation work focuses specifically on the interplay between self-regulation and learning to code.

Marina Umaschi Bers is a professor at the Eliot-Pearson Department of Child Development and the Computer Science Department at Tufts University. She heads the interdisciplinary Developmental Technologies research group which focuses on designing and studying innovative learning technologies to promote positive youth development. Dr. Bers received prestigious awards and has written two books "Blocks to Robots: Learning with Technology in the Early Childhood Classroom" (2008; Teacher's College Press) and "Designing Digital Experiences for Positive Youth Development: From Playpen to Playground" (2012; Oxford University Press). Dr. Bers has an M Ed from Boston University and an MS and PhD from the MIT Media Lab. More on Dr. Bers: http://www.tufts.edu/~mbers01/