Exploring the Impact of Students' Experiences in Applied Research on Perceptions and Success in ICT Capstone Projects: A Pilot Study

by

Peter Callaghan

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Abstract

Despite offering students valuable experience and connections to potential employers, the educational benefits of engaging in applied research projects are not well understood. This study explored what these potential benefits may be by examining how applied research experience impacts students' experiences in capstone courses in the field of Information and Communications Technology (ICT). Twenty-two students (18 males, 4 females) between the ages of 18 and 40 attending two programs at a college in Toronto, Ontario, Canada completed a survey upon completion of their capstone course. Four of these students had applied research experience, six had some other form of work experience, and 12 had no experience other than their coursework. The answers given by participants from each of the three groups were compared to determine areas that are potentially interesting for future research. Six areas of potential differences were identified based on previous studies on capstone projects and problem based learning and included students' views of personal skill level, team member's skill level, preparation for capstone projects, importance ratings of skill , satisfaction with capstone projects, and satisfaction with team members.

The participants who had applied research experience expressed more confidence in their abilities than the other groups and the participants with work experience expressed less confidence than the other students.

The participants who had applied research experience rated their team members as less capable than themselves, while the participants who had work experience rated their team members as more capable than themselves.

The participants with no experience and the participants with work experience rated the preparatory quality of their course work very similarly to how they rated their own skills, while the participants with applied research experience rated their courses somewhat lower than their skills.

Regardless of experience, the participants in this study rated the four skills (communication, time management, teamwork, and technical/programming) as important.

The overall consensus from the participants in this study was that all three groups were moderately satisfied with their projects. The older participants also expressed viewing it as a useful tool for future employment, either as good experience or something to place on their resume.

Finally, all three groups generally agreed that they were satisfied with the work of their team members.

Due to the small sample size, this study can not indicate any statistically significant findings between participants' experiences and their views regarding the various skills, but it does identify potentially promising areas for future research.

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1 Introduction

1.1 Overview

Post-secondary programs in Information and Communications Technology (ICT) often include a capstone project course as a culminating task. While the exact implementation of these courses varies between schools, they share many common features and a similar intent (Lynch, Goold, & Blain, 2004; Keller, Parker, & Chan, 2011; Keogh, Sterling, & Venables 2007). Capstone projects expose students to projects that are much larger and more complex than what is typically possible in a traditional course. Capstone projects are designed to reflect the size and complexity of problems that students are likely to encounter after graduation (Keller et al., 2011; Venables & Tan, 2009). In addition to providing an introduction to the practices of professionals in their chosen field of study, capstone projects serve to develop several important 'soft' skills that are regularly identified as essential to students' success within their programs and in professional practice (Lynch et al., 2004; Pilskalns, 2009). These capstone projects are often a source of frustration for students, with many stating that they do not feel prepared for them, despite having several years of traditional course-work experience. In addition, a number of students fail to complete their capstone projects due to shortcomings in the same skills that these projects were designed to develop (Ikonen & Kurhila, 2009; Stein, 2003; Venables & Tan, 2009; Zhang & Wang, 2011).

The college examined in this study includes a department that regularly employs student researchers in an environment very similar to problem based learning, as described by Howard Barrows (1986) and described in more detail in the literature review below. Problem based learning (PBL) provides a useful lens to examine possible improvements to curricula in order to better prepare students for their capstone projects and professional work. Many of the key

aspects necessary for a course to be considered PBL, such as teamwork, complex open-ended problems, and self-directed learning are also present in standard implementations of capstone projects.

Since PBL has been found to improve students' ability to recall and apply knowledge (Kirschner, Sweller, & Clark, 2006; Strobel & van Barnevald, 2009; Thomas, 2000), students who have experience in PBL through applied research may have an advantage over students who have no such experience. This study examined if students' experience in a PBL-like applied research environment may have an impact on students' perceptions of their own skills, and those of their team members, as well as their views on the importance of those skills. The specific skills examined included time management, teamwork/coordination, communication, technical/programming skills.

2 Literature Review

2.1 Overview

This literature review begins by examining the design of capstone projects commonly implemented in ICT programs, including the educational benefits of integrating these projects into post-secondary curricula, the challenges inherent in running, and taking, a capstone project course, and key factors that have been identified as being essential to student success in capstone projects. Next it examines problem based learning (PBL), the underlying features that must be present for a course to be considered PBL, and four key educational principles of PBL: structuring learning in a clinical context, motivating the learner to take ownership of the learning process, self-directed learning, and the development of effective clinical reasoning. Finally, this literature review examines how the key features of PBL are present in standard implementations of capstone projects, even when they are not explicitly described as being 'problem based learning'.

2.2 Capstone Projects

Many post-secondary ICT programs include some form of capstone project as a culminating task, giving "students the opportunity to develop, refine, and evaluate their technical knowledge and skills in work-like situation, and work in teams in preparation for their future professional employment" (Lynch et al., 2004, p. 431). While the details of how such projects are implemented vary between different schools, they share many of the same features (Lynch et al., 2004; Keller et al., 2011). Most of the different designs of capstone projects described by Lynch et al. (2004) and suggested by Keogh, Sterling, and Venables (2007) involve students gaining valuable 'real-world' experience by taking an active part in the design and development of a complex software project, beginning with the initial stages of gathering requirements from

clients, continuing with the development and testing of a solution, and the delivery or deployment of a finished product. Capstone projects are often completed for someone acting as a client who might be a contact from a local business or a faculty member (Keller et al., 2011). The exception to this design is the studio model described by Lynch et al. (2004), which does not have a client, but instead has an external industry contact acting as a mentor to the students and not expecting to use the completed project.

Regardless of the design chosen, capstone projects present similar strengths, challenges, and factors that are keys to project success. As an integral part of developing the project, the students involved exercise and improve their time management, team coordination, and communication skills (Lynch et al., 2004; Pilskalns, 2009). These same skills are often under-developed through more typical course-work, and this presents significant challenges during capstone projects (Keller et al., 2011; Pilskalns, 2009; Stein, 2003; Venables & Tan, 2009; Zhang & Wang, 2011).

2.2.1 Capstone Benefits

Capstone ICT projects bear a number of potential benefits for all involved. Students gain project management experience while developing and applying essential workplace skills (Grant, Malloy, Murphy, Foreman, & Robinson, 2010). The project clients receive a software application designed to meet their specifications (Grant et al., 2010). These projects also help students to develop and exercise a variety of 'soft' skills such as communication, time management, and teamwork (Keller et al., 2011; Keogh et al., 2007; Lynch et al., 2004; Pilskalns, 2009; Venables & Tan, 2009).

While students, faculty, and employers identified these skills as important both for project success and future employment (Grant et al., 2010; Ikonen & Kurhila, 2009; Keller et al., 2011;

Keogh et al., 2007), Venables and Tan (2009) found that the skills typically remain underdeveloped through traditional courses. Venables and Tan (2009) noted that typical courses do not prepare students for the practical challenges of adopting new technologies, while Keogh et al. (2007) reported that employers highly value such flexibility and independent learning.

Capstone projects provide students with an opportunity to develop employability skills, while gaining experience and connections with potential employers (Keller et al., 2011; Keogh et al., 2007). In the capstone design studied by Keller et al. (2011), students improved communication skills through tasks such as interviewing their client about project goals, negotiating the scope of the project, and presenting the completed project to them. This presentation in particular was identified by the students as very useful, as it required them to practice presenting technical information to a non-technical audience, a skill they felt they would likely need (Keller et al., 2011).

Capstone projects are also identified as creating bonds between faculty, industry, and students, which can be beneficial even to those students not involved in a capstone project. Person and Rosenbaum (2005) noted that even the perception of a link between faculty and industry predicted increased effort from students. Anderson (2001) found that when there was the potential for the client to employ the students after the end of the project, those students demonstrated increased motivation and engagement, as they desired to produce a product that would satisfy a prospective employer.

The combination of developing students' time management, communication, and teamwork skills, combined with increased motivation is particularly effective at promoting student success, both within the capstone and beyond (Keller, 2011; Lynch, 2004; Pilskalns, 2009; Zhang, 2011). The students' soft skills are also noted as being challenges to successful

completion of capstone projects, as they remain undeveloped due to their absence from most typical courses.

2.2.2 Capstone Challenges

Capstone projects do not come without challenges. The students, faculty and industry partners each have potentially competing expectations of what they will take away from the project. Next, students often enter capstone projects lacking the soft skills they will need to complete it. A third major challenge is the sheer amount of time and effort required of the faculty advisor.

The first major challenge in capstone projects is that the groups involved (students, industry, and faculty) each have expectations of what they will take away from the project, which do not necessarily align with each other. Faculty will generally be concerned with the experiential learning aspects of the project course (Keogh et al., 2007). They will focus more on the learning process of project development than on the creation of a working product (Keller et al., 2011). Ikonen and Kurhila (2009) suggested that even a failed project can be a success, as it gives the students a chance to reflect on the process involved in large projects, an opportunity typically missing from standard course work.

However, the faculty focusing on process over product in a capstone project can create a conflict with the client, as the client expects a working piece of software when the course is complete (Grant et al., 2010). Keogh et al. (2007) identified a way to mitigate this conflict by choosing projects that, while useful to the client, are not essential to their business. This allows the students some freedom to learn by making mistakes, meeting the educational goals of the course, without harming the client's business if the group does not produce a working application. Even when the project is not successful the client at least receives detailed

documentation of the software they wish to have developed, along with knowledge of some things that did not work (Keogh et al., 2007).

The second major challenge is that the soft skills identified as being important for employment and as being developed through capstone projects were also commonly acknowledged as significant factors in a project's failure when they were not effectively applied. Students, particularly those whose projects were not successful, regularly recognized failures in communication, time management and team management as causative factors (Keogh et al., 2007; Umphress, Hendrix, & Cross, 2002).

Although students did not generally rate their programming/technical skills very highly (Zhang, & Wang, 2011), a lack of technical skills were rarely identified as a cause for the failure of a project (Ikonen & Kurhila, 2009; Venables & Tan, 2009; Zhang & Wang, 2011). Despite finding that the technical skills students had learned in traditional courses did not translate well to the scale of capstone projects (Umphress et al., 2002), students expressed more concern over teamwork and collaborative learning (Keogh, el al., 2007). Students were more likely to identify communication, time management, and team coordination skills as being integrally related to the success or failure of the project, and many entered their capstone projects not feeling confident in their proficiency with these skills (Keogh et al., 2007; Zhang, & Wang, 2011).

The third major challenge is that faculty require significant preparation time before and during capstone project courses. Before the course begins, necessary steps can include contacting and screening potential clients (Keller et al., 2011), discussing what the clients should and should not expect from the students, and screening the potential projects for suitability as student capstone work (Keogh et al., 2007; Venables & Tan, 2009). Keogh et al. (2007) noted that the preparation process can become simpler over time, as faculty can form ongoing

relationships with a number of clients who may provide further projects if their first experience is a good one. However Anderson (2001) noted that contacts gained through similar academic industry relations are often linked to the faculty member forming the connection, and not the institution, so that other faculty and their students may not be able to take advantage of the established partnership.

2.2.3 Key Factors for Success

Students' underdeveloped soft skills and the significant investment required in faculty time and effort are challenges that must be overcome for students to gain the full benefits of such a course. The literature identified two key factors for success that can mitigate these issues and increase the likelihood of students successfully completing a project. These include developing the students' soft skills prior to the capstone, and identifying the link between the work done and the potential for future employment.

The same 'soft' skills identified as being developed through capstone projects were also often cited as being significant determining factors in the success or failure of a project (Ikonen & Kurhila, 2009; Zhang & Wang, 2011). Even students who rated themselves with relatively poor programming skills could contribute to a successful project when the team could effectively coordinate the work of the individual members (Zhang & Wang, 2011). However teams often experienced significant issues if the size of the team was beyond their ability to coordinate (Pilskalns, 2009). Students placed high value on lectures and activities that would develop their communication and coordination skills, such as how to interact with their client and team members (Keogh et al., 2007).

Grant et al. (2010) noted that linking the success of the project with the potential for future employment, either with the client or simply the potential to perform similar work after

graduation, proved a powerful motivating factor for students. The increased motivation improved not only the quality of the work done, but student's satisfaction with their work, both of which have been identified as being correlated with project success (Ikonen & Kurhila, 2009). Keogh et al. (2007) also noted an increase in student satisfaction and confidence after completing the high-quality, realistic work a capstone project entails.

Finally, Ikonen and Kurhila (2009), as well as Lynch et al. (2004) noted that students commonly expressed a desire for clearer project goals - the presence of such goals improved the prospects for a successful project and increased student satisfaction. As common designs for capstone projects leave the details of the goals to be negotiated between the students and their faculty and client, this once again links the student's communication skills to the success of the project (Lynch et al., 2004; Keller et al., 2011).

If clear goals, increased motivation, and development of student skills can be incorporated into the project, or the lead up to the course, students' chances for successfully completing their projects can be improved.

2.3 Problem Based Learning Design

One possible method for providing students an opportunity to practice and develop their soft skills (time management, teamwork, and communication skills) prior to a capstone project is through problem based learning (PBL). Recent studies have reported that PBL has a number of potential advantages over traditional classroom arrangements, particularly in developing students' abilities to apply their knowledge to novel situations and to communicate that knowledge to others (Dahlgren & Dahlgren, 2002; Dochy, Segers, Van den Bossche, & Gijbels, 2003; Strobel & van Barnevald, 2009; Thomas, 2000). Problem based learning also provides experience using the same skills that are identified as being essential to capstone projects,

namely teamwork, time management, and communication (Dunlap, 2005; Savery & Duffy, 2001). However, proper implementation of PBL is required for students to gain experience in exercising the identified skills through using them in a context that simulates the environment they will eventually need them.

The original designer of PBL, Howard Barrows (1986), has described a very specific process for implementing effective PBL. First, the problems used in PBL must reflect or simulate real-world problems that students might later encounter. The problems the students are solving must be complex enough to provide a reasonable challenge to the learner, while not being beyond their abilities. The information necessary to solve the problem may not be available at the start, and there is no one 'right' answer to any problem complex enough to be used in PBL (Barg et al., 2000; Dolmans, De Grave, Wolfhagen, & Van Der Vleuten, 2005; Savery & Duffy, 2001).

Second, PBL needs to be conducted in groups to support real-world practice and the developing teamwork skills (Barg et al., 2000; Dunlap, 2005; Dolmans & Gijbels, 2013; Loyens, Gijbels, Coertjens, & Cote, 2013; Schmidt, Loyens, van Gog, & Paas, 2007). An advantage of the team process is that students can share knowledge with each other, build on the knowledge of their group, access more resources, and explore more potential solutions than an individual could (Dolmans et al., 2005; Savery & Duffy, 2001).

Third, when approaching PBL it is important that groups discuss what is known about the problem in the context of what they already know and identify potential solutions based on that knowledge (Barrows & Kelson, 1993; Dolmans & Gijbels, 2013; Loyens et al., 2013). This preliminary discussion creates connections between the students' existing knowledge and the new problem (Schmidt, 1993; Schmidt et al., 2007). The students then identify information that

must be gathered and research that must be done in order to determine which solution is best. Each member takes responsibility for a task/area to explore, then the group breaks up and each pursues their task. Once their individual research is complete the group re-convenes to discuss what they have learned and re-examine the problem in light of the new information. These follow-up meetings involve the students gaining understanding of what the others researched, and determining what they have learned as a group. The process of identifying issues, breaking them into tasks for each team member, researching and meeting to resolve them, may be repeated several times if there are still things the students need to discuss.

When the students are satisfied with their solution to the problem, the group prepares a report/presentation to be made to their peers, their instructor, and often an external 'stake-holder' reviewer. The presentation includes their solution, but it is also important that it discuss how the students reached that solution. Barrows and Kelson (1993) recommend that the presentation and other assessments focus on the learning process, more than the solution itself, as it is the process of learning and problem solving that is important, more so than the problem being solved.

Barrows and Kelson (1993) also stated that during PBL it is important that the faculty not act as a transmitter of knowledge; they are there to guide the students through the process and help students reflect on what they are learning, but the students must be in control of that learning (Loyens et al., 2013; Strobel & van Barnevald, 2009). While faculty may answer students' questions, as in the case of medical examples, to act as though the student was running further tests or consulting a specialist, faculty are primarily there to facilitate the learning/problem-solving process and to ask students questions they should be asking themselves (Dolmans et al., 2005; Savery & Duffy, 2001; Strobel & van Barnevald, 2009). For example, when the students reach a conclusion, the faculty might ask why the students believe that

conclusion to be correct, explicitly drawing the students into a meta-cognitive process (Dolmans & Gijbels, 2013; Dunlap, 2005; Savery & Duffy, 2001; Strobel & van Barnevald, 2009).

Throughout the problem solving process, Barrows (1986) identified four key things that must be considered for PBL to be effective: structuring learning within a clinical context, motivating the learners to take ownership of the problem, applying a clinical reasoning process, and self-directed learning.

2.3.1 Structuring Learning in a Clinical Context

It is important that the problems being solved reflect the complexity and open-endedness that students will encounter following graduation (Barrows & Kelson, 1993; Dunlap, 2005; Loyens et al., 2013; Newman, 2005; Schmidt et al., 2007). Instead of finding a single 'right' answer, students' efforts are devoted to understanding the problem, and dealing with it as they would in a 'real' clinical context.

The PBL process includes explicitly calling on previous knowledge to gain an understanding of the problem in light of what is already known before identifying gaps in current knowledge. Those gaps in knowledge are then used to drive research towards finding a solution to the problem (Schmidt et al., 2007). This explicitly links the knowledge being gained to the students' existing understanding, so that it will be recalled more readily in-context, and helps the students to develop a thorough understanding of their workplace (Dolmans et al., 2005; Schmidt, 1993). By modeling a workflow process and the kind of deductive reasoning that professional practice demands students graduate better prepared to solve complex problems and to further their own learning when there will no longer be an instructor telling them what they need to know (Dunlap, 2005; Savery, 2006; Savery & Duffy, 2001).

While students trained using PBL showed no significant gain, and in some cases marginally lower, scores on tests that required memorization of facts, they consistently scored higher on tests requiring problem solving and applying their knowledge, and were capable of recalling the information they knew significantly longer than students who had been trained in traditional lecture-based classes (Dahlgren & Dahlgren, 2002; Dochy et al., 2003; Strobel & van Barnevald, 2009). The linking of these problems and how they can be solved to the context of future tasks also provides important motivation to the students.

2.3.2 Motivation

The next educational objective of PBL is motivation (Barrows, 1986). By having a complex problem that is deeply rooted in what students are likely to encounter after graduation and allowing the students to determine what they need to learn next, they become more engaged with the learning process, and more motivated to develop a deeper understanding (Barrows, 1986). The learners can see the problem as more than just 'busy-work' required to earn a mark, but as practice and preparation for what they will be required to do in a workplace setting (Savery & Duffy, 2001).

There is also an aspect of peer-recognition and not wanting to let their group down, as the learners will need to return to their peers and present what they have learned to their group before agreeing on a solution which they will typically present to the entire class (Schmidt, 1993). The solution they present will be their own solution, not the instructors. It is likely that each group will have different solutions, and each student will have had to discuss their group's solution with their peers, understanding other possible solutions based on what the other group members have found, as well as having adequate knowledge and preparation to defend their own solution if they believe it is the best one (Dolmans et al., 2005; Savery & Duffy, 2001).

The student groups then need to explain to their peers, their instructor, and possibly an external 'stake-holder' why they believe their solution is correct, as well as how they reached it. While some studies found that this increased the amount of time students took on their work, this appeared to be time they were willingly spending in order further to their understanding (Loyens et al., 2013; Schmidt, 1993).

2.3.3 Clinical Reasoning Process

Another major focus of PBL described by Barrows (1986) is developing the reasoning/problem solving skills that students will eventually need in professional practice. Memorization and recall of facts is not sufficient for many fields, instead students will require the ability to research new information in order to understand new problems without an instructor telling them what they need to know, and where to find it (Barrows, 1986; Dolmans et al., 2005; Strobel & van Barnevald, 2009; Thomas, 2000). Learners must also be able to judge the merits of the potential solutions they devise, as again, there will be no instructor to tell them that it is the correct answer, and they must be able to describe their solution to their co-workers & supervisors.

Even if graduating students are not immediately placed in such a situation, work in many fields requires working in coordination with a team, combining the learners reasoning processes with those of their co-workers, and PBL models this practice (Barg et al., 2000; Barrows & Kelson, 1993; Savery, 2006, Savery & Duffy, 2001; Schmidt et al., 2007).

2.3.4 Self-Directed Learning

The final factor identified by Barrows (1986) is developing the students' capacity for self-directed learning. After graduating, students will no longer have an instructor telling them what to learn, or evaluating them on how well they have learned it; they will simply be expected to

continue to develop their own skills. The learners must be prepared to continue learning under their own direction, with the ability to identify shortcomings in their knowledge and understanding of a problem, and to be able to find resources to rectify those weaknesses, evaluate them for quality and appropriateness to the task at hand, as well as manage their own time dedicated to learning (Dolmans et al., 2005; Savery, 2006; Schmidt et al., 2007).

Self-directed learning is developed in two ways during PBL. First, during the group meetings, the students are the ones who identify what it is that they need to learn in order to solve the problem. Second, when students conduct their search for resources to use, they are the ones who must evaluate those resources for quality and appropriateness to the task at hand (Barrows & Kelson, 1993; Savery & Duffy, 2001).

2.4 Problem Based Learning in Capstone Projects

The ICT capstone course environments described in the literature shared many of the essential features of PBL, even if not explicitly designed as such (e.g., Barrows, 1986; Barrows & Kelson, 1993; Keller et al., 2011; Lynch et al., 2004). All of them required working in groups on a project of non-trivial size (e.g., Dolmans et al., 2005; Newman, 2005; Pilskalns, 2009; Zhang & Wang, 2011). In most cases the project is being developed for a real client, so students are not just modeling real-world practice, but living it (e.g., Loyens et al., 2013; Lynch et al., 2004; Schmidt et al., 2007; Venables & Tan, 2009). The student groups negotiate with faculty and/or the client to determine the exact requirements of the project, the details of which will not be clear at the outset of the project but will require students to undertake research and problem solving in order to find an acceptable solution, or possibly to determine that what was planned is not possible and must be revised (e.g., Dahlgren & Dahlgren, 2002; Pilskalns, 2009; Strobel & van Barnevald, 2009; Walker & Leary, 2009).

The nebulous nature of the solution for a capstone is important, as it forces the students to exercise the complex reasoning processes they will need when solving problems outside the confines of an academic environment, including examining multiple possible solutions and evaluating each based on its merits (Barrows, 1986; Dunlap, 2005; Savery, 2006).

The student-driven selection of projects and determination of the exact details of each project should lead to increased motivation and interest in the problems being solved (Barrows & Kelson, 1993). The fact that the most of the projects are real-world problems that will be used by others after completion of the project reinforces the importance of the skills learned during these courses and the motivation to produce high-quality work. This link between what is learned and what goes on in industry is a key feature of PBL (Barrows & Kelson, 1993; Dunlap, 2005; Loyens et al., 2013;Schmidt et al., 2007). Similarly, the potential for future employment based on the work done is recognized as a powerful motivating factor (Pilskalns, 2009).

When there is a client, they are expecting a working application at the end of the project, so there is necessarily some focus on the solution created, however the faculty still has the capability to assess at least partially on process over product if they choose to do so. In some cases (notably the courses that were surveyed in this study) there is also some form of presentation to peers at the end of the project, allowing groups to see what others have done and learned.

2.5 Summary

Despite there being a variety of designs for capstone projects, common factors include working in teams on open ended problems, planning research and implementing solutions that reflect the size and complexity of real-world problems that the students will encounter after graduating. In many cases these projects go beyond simply simulating future professional work,

as they involve a real-life client who intends to use the project the students develop. In capstone projects, skills such as communication, time management, and the ability to work effectively in a team were frequently identified as being required for project success, and blamed for project failure when absent or under-developed. These same skills were also repeatedly identified as being developed through capstone projects, and under-developed in other course work. These skills, combined with student motivation, are noted as being the most significant determining factors in the success or failure of a capstone project, and must be considered in any study regarding capstone projects in ICT.

Problem based learning presents a very similar environment to the various designs of capstone project courses described in the literature. It requires students to work in small teams to build their understanding of a complex problem, which they will devise potential solutions for. The students then conduct relatively independent research to refine their solutions, before the group reconvenes to determine which solution they would implement. They then present that solution to their peers, their faculty, and possibly an external reviewer.

2.6 Overall Research Question

While capstone projects and applied research bear many of the same hallmarks, and require the exercise of similar skills regarding teamwork, time management, and communication, it is not yet clear if applied research experience has any noticeable impact on those skills. The purpose of this study was to determine what impact experience in an applied research project has on students' perceptions of the skills identified as essential to their success. For example, whether they feel more or less prepared than other students, and whether they rate the importance of the skills any differently.

3 Method

3.1 Setting

This study took place at a college in Toronto, Ontario, Canada. The college has over 100,000 full and part-time students across more than 150 programs and 10 Campuses. Participants for this study were drawn from two programs in the school of Information & Communications Technology (ICT), within the Faculty of Applied Science and Engineering Technology which has a total enrollment of approximately 5000 students.

3.2 Sample

Students in three capstone project courses in two programs in the school of ICT were selected as potential participants in this study. Of the 76 students available from three courses, 22 volunteered to take part in the study. The capstone courses take place in the third year of both programs, one of which is a three year diploma, while the other is a four year bachelor's degree. Eighteen of the participants were male, four female. This uneven division was expected as the population of the programs is approximately 90% male. The age of the participants who responded to the study ranged from 18 to 40, with the majority (68%) in the range from 21 to 25. Based on their answers to one of the demographic questions the participants were divided into three groups: research experienced, work experienced, and inexperienced. The "research experienced" group consisted of four participants who had participated in applied research projects. The "work experienced" group consisted of six students, two of whom reported having some other form of work experience in ICT, three who reported having taken co-operative work terms prior to their capstone project course, and one student who reported having both co-op and related work experience. The "inexperienced" group consisted of 12 students who reported having no ICT related work experience. The possibility of combining the two experienced

groups into one was rejected as the type of work the students with work or co-op experience described having done did not match the definitions of PBL.

3.3 Program Description

All four of the participants in the "research experienced" group were male and between the ages of 21 and 30. Two were from the diploma program, two from the degree. The "work experienced" group ranged in age between 18 and 40 and included one student from the diploma program and one of the female participants. The 12 participants in with no experience ranged from 18 to 40 years old, though the majority (75%) were between 21 and 25. Three of the four female participants were in the inexperienced group. All of the participants from all three groups had completed their capstone course.

Several studies and meta-analyses of PBL (Barg et al., 2000; Dolmans et al., 2005; Strobel & van Barnevald; Thomas, 2000; Walker & Leary, 2009) noted that many studies that claim to be using PBL provide few details of how they implemented it, raising questions of whether or not the studies in question were all using the same definition of problem based learning. To avoid that problem here, a detailed description is given of how the applied research experience and the capstone projects meet Barrows' requirements for PBL.

3.3.1 Applied Research Experience

The applied research environment at the college being studied represents many of the key aspects of PBL and has an underlying focus on continuing self-directed learning.

Like the students in the capstone projects, student researchers participate in determining the requirements and implementation design for the research projects. They also exercise some control over the exact features they work on over the course of the project, in many cases choosing specific details from common issue-tracking systems. These projects are always

developed in collaboration with an industry partner, acting as a stake-holder, who expects to have a working product once the applied research work is complete. The student researchers work in teams, with close communication between the team-members and others working on the project. The pool of others working on the project can be significant, as these projects are open-source and connect the student researchers to a larger professional environment, allowing them to experience working with others in their industry. In several cases this has lead to the student researchers later being employed by their industry partner, or others, to continue work on the project.

Throughout the duration of the projects, which often last for several four month semesters, the student researchers are encouraged (in some cases required) to reflect on lessons learned and their work process through regular blog-posts as well as meetings and presentations within and between research teams consisting of both students and faculty advisors. The faculty advisors do not take a direct hand in the development of the projects, but help guide the student researchers in their work in a manner very similar to the facilitator/tutor role in PBL.

3.3.2 Capstone Course

Working in small teams, students research, design, and develop a significant software application over the course of two semesters. The first semester focuses mostly on planning the project, while the second entails the actual implementation. Where possible, students work with an industry partner from a local business, with the instructor acting as a client/stakeholder when no such partner is available. During the early stages of planning, students negotiate with the industry partner to determine the features to be implemented, with the faculty member ensuring that each project represents a reasonable challenge for the teams, without being more than they can be expected to accomplish.

During both the planning and implementation courses, the student groups have regular meetings with their faculty advisor to discuss what they have accomplished and what they intend to work on next. The quality of these meetings as part of a PBL experience depends largely on the faculty member, just as the quality of meetings in traditional PBL courses depends on the skills of the faculty/tutor. This usually entails the students explaining what they have done, and why, however it may result in the faculty directly telling the students to change some part of their design. While direct intercession by faculty undermines the view of these courses as a PBL environment, it is still up the student to research that aspect of the solution and to integrate it into the project as a whole. This weakness is also shared with many other courses identified as PBL (Dolmans et al., 2005; Savery & Duffy, 2001; Strobel & van Barnevald, 2009), and enough of the other details still closely align with Barrows' concepts of key learning objectives for PBL to be an accurate analysis tool.

As the details of many capstone projects are designed and negotiated in conjunction with an industry partner, there is no pre-planned 'correct' implementation. Even in the cases where a project does not have an industry stakeholder, a faculty member acts as a client and the scale of the project is designed to allow similar complexity to a PBL environment.

Within the project groups students divide up responsibility for various parts as they see fit, working collectively to determine solutions and to design and implement their project. Between meetings with each other, the students work in relative isolation to research potential solutions, evaluate them, and determine if they will fit into the final project before returning to the group to discuss what they have learned. This is almost identical to the process groups use to develop solutions in PBL, and is closely aligned with Barrows' concepts of self-directed learning and the clinical reasoning process as being important to PBL.

When the project is complete, the students present the finished design to the faculty and the industry stake-holder. These presentations mirror Barrows' suggestion that students exercise multi-media presentation skills as will be practiced in industry (Barrows & Kelson, 1993; Savery, 2006). Just as in PBL, the students often present to the other students in their course (who were working on different projects), leading to discussions about implementation details, decision making, and lessons learned.

3.4 Procedure

Students who completed the capstone project courses from two ICT programs were sent an email one week before the end of the Winter 2013 semester explaining the purpose of the study (see Appendix B) and requesting their participation in filling out an 10-15 minute online survey (See Appendix A) which was made available after the end of their project, but before the final marks were posted. Only eight out of 76 students registered in the courses chose to participate

Therefore, at the beginning of the next semester, a second attempt was made to gather more data using a different approach. A five minute, in-person explanation of the study, derived from the email invitation (see Appendix B), was given to the students enrolled in a course which followed directly after the capstone project in the degree program. The students were then given the opportunity to complete a paper copy of the survey that had been available online. Fifteen out of the 17 students present completed the survey, taking up to fifteen minutes to do so.

In summary, of the 76 students contacted through email and the in-class presentation, a combined 22 agreed to participate (29%), with the majority of those filling out the paper survey and being drawn from the degree program.

3.5 Data Collection Tools

The survey used in this study was divided into three parts, each of which is described in more detail below.

Part 1 – Demographics. The first part of the survey consisted of four demographic questions (age, gender, program, and prior experience – see questions 1 through 4 in Appendix A). The demographic questions served a dual purpose of describing the sample, and dividing the participants into the three groups (research experience, work experience, and no experience).

Part 2 – Likert questions. The second portion of the survey consisted of six five-point Likert scales (ranging from 1 - 'Strongly Disagree' to 5 - 'Strongly Agree' see questions 5, 6, 7, 11, 14, and 16 in Appendix A) representing six key areas: adequacy of critical skills, adequacy of team members' critical skills, preparation in critical skills, importance of critical skills, satisfaction with the capstone project, and satisfaction with their team members. Each of these questions had between three and five sub-statements, for a total of 18 Likert scales.

Part 3 - Open-ended questions. The third portion of the survey contained five open-ended questions, each of which is linked to one or more of the Likert question groups. Most of these questions were intended to add more detail to the information gathered through the Likert scales, in hopes that the reasons behind ratings would become clear (e.g., why students felt a particular skill was important). Question 8, which asked participants to identify types of work they had done in the past (if any), served two purposes. While it was primarily used to obtain more data on factors that had prepared them for their capstone projects, it also established that the experience described by participants who had workplaces or co-op experience did match the features required to be considered PBL (Barrows, 1986; Barrows & Kelson, 1993). This prompted the decision to consider them as a separate group from the participants who had applied research experience.

3.6 Key Themes Assessed

Six key areas were assessed including the participants' critical skills, their team members' critical skills, their preparation in critical skills, the importance of the critical skills, satisfaction with the capstone project, and satisfaction with other team members.

Adequacy of critical skills. Likert questions 5a through 5d asked participants to rate themselves in each of four skill areas identified in the literature as being essential for project success (Keller et al., 2011; Pilskalns, 2009; Stein, 2003; Venables & Tan, 2009; Zhang & Wang, 2011). Three of these skills (communication, time management, and teamwork) are soft-skills, which the literature identifies as being primarily developed through capstone project work, and under-developed in typical coursework (Keller et al., 2011; Lynch et al., 2004; Pilskalns, 2009; Stein, 2003; Venables & Tan, 2009; Zhang & Wang, 2011).

Adequacy of team members' critical skills. In Likert questions 6a through 6d the participants rated their team members from the capstone project on the same four skills (communication, time management, technical, and teamwork) they had rated themselves. As the team dynamic is important to both capstone projects, and PBL (Barg et al., 2000; Dunlap, 2005; Ikonen & Kurhila, 2009; Lynch et al., 2004; Loyens et al., 2013; Pilskalns, 2009; Zhang & Wang, 2011), this group of questions examined if the participants with experience viewed their project teammates differently from those who did not have experience.

Preparation in critical skills. Participants used five Likert questions 7a through 7e to rate how well they felt they had been prepared for the rigors of capstone project work. Three open ended questions were included to gather data for this research question: Question 8 asked participants to elaborate on any previous work experience they had, question 9 asked them to identify any other factors they felt had been important in preparing them for their projects, and question 10 asked participants to provide information on things they would tell students starting

a project (i.e., preparation they felt they had been lacking). As most students in capstone projects expressed feeling unprepared (Keller et al., 2011; Pilskalns, 2009; Stein, 2003; Venables & Tan, 2009; Zhang & Wang, 2011), this examined if students with experience felt any more or less prepared than non-experienced students.

Importance of critical skills. Likert questions 11a through 11d were used to gather information on how participants rated the importance of the three soft-skills identified in the literature as being primarily developed through capstone project work (communication, time management, and teamwork), along with technical/programming skills (Keller et al., 2011; Lynch et al., 2004; Zhang & Wang, 2011). Open ended questions 12 and 13 asked participants to identify other factors they felt were integral to the success or failure of their project, and what other factors had been important in preparing them (i.e., were there any other skills that they felt were important).

Satisfaction with the capstone project. Likert questions 14a through 14c asked participants to rate how satisfied they were with their project, how well the felt it reflected their abilities, and whether they felt their project was a success. One open ended question (question 15) asked participants to provide more detail on whether they felt their project was a success or failure, and why. Several studies linked students' satisfaction with their work to the success of the project (Ikonen & Kurhila, 2009; Keogh et al., 2007; Strobel & van Barnevald, 2009), and this group of questions examined if participants with experience expressed more or less satisfaction with the work done than the participants with no prior experience.

Satisfaction with team members. Likert Questions 16a through 16c asked participants to rate how satisfied they were with their work, and the work of their team members and whether they would be willing to work with their team members on further projects. Answers to question

17 were also intended as part of this section as it was expected that some answers given would reference the work of team members. This group of questions examined if there is a possible correlation between the work of team in a project, and a students' satisfaction with project itself. Such a correlation seems likely as teamwork is a common topic in the literature (Barg et al., 2000; Dunlap, 2005; Ikonen & Kurhila, 2009; Keogh et al., 2007; Lynch et al., 2004; Loyens et al., 2013; Pilskalns, 2009; Strobel & van Barnevald, 2009; Zhang & Wang, 2011).

3.7 Research Design and Data Analysis

This mixed-methods study combined 18 five-point Likert scale questions with five open-ended questions in order to examine participants' perceptions of skills (their own, and those of their team members) in capstone projects. These questions were divided into six groups based on the research questions identified earlier.

It was initially intended that the responses the participants gave to the Likert scale questions would be compared using independent t-tests, however the overall sample size was so small that the intended statistical measures would not be meaningful. Descriptive statistics are used to examine features of the participants in this study in order to inform areas of potential interest for future research. In addition, due to the different forms of experience reported, the participants were divided into three groups instead of the planned two.

The answers participants gave to the open-ended questions were broken into individual statements, with each statement being transcribed onto a card with the demographics information copied onto the back. These cards were then sorted using Glaser's constant comparative method of data analysis (Glaser, 1965), allowing the answers given to define the themes that would emerge. Each card was examined in turn to determine if it fit into one of the pre-identified themes, or if the themes needed to be refined to accommodate the emerging information. This

was intended to allow the participants to identify other areas they felt were important to their experience in their capstone project, not just those already identified by participants in previous studies from other institutions.

3.8 Key Research Questions

The key research questions are as follows:

1. What is the difference in perception of personal skill levels (teamwork, time management, communication, and technical/programming) between students who have prior applied research experience (Experienced) and those who do not (Inexperienced)? (Liker questions 5a through 5d – Appendix A).
2. What is the difference in perception of team members' skill levels between experienced and inexperienced groups? (Likert questions 6a through 6d – Appendix A).
3. What is the difference in perceptions of preparedness for realistic projects between experienced and inexperienced groups? (Likert questions 7a through 7e and open ended questions 8, 9, and 10 – Appendix A).
4. What is the difference in students' perceptions of the importance of skills between experienced and inexperienced groups? (Likert questions 11a through 11d and open ended questions 12 and 13 – Appendix A).
5. What is the difference in students' satisfaction with their own work in capstone projects between experienced and inexperienced groups? (Likert questions 14a through 14c and open ended question 15 – Appendix A).
6. What is the difference in students' satisfaction with the work done by their team members in capstone projects between experienced and inexperienced groups? (Likert questions 16a through 16c and open ended question 17 – Appendix A).

4 Results

Six key research questions were addressed in this pilot research study. The results for each are discussed in turn below.

4.1 Adequacy of Critical Skills

The questions in this section asked the participants to rate themselves in each of the four skill areas (communication, time management, technical/programming, and teamwork), the results of which are displayed in table 1.

Table 1
Students' Views of the Adequacy of Their Skills, Divided by Experience

	Research Experience		Work Experience		No Experience	
Statement	*n*	*M* (*SD*)	*n*	*M* (*SD*)	*n*	*M* (*SD*)
I feel I had adequate communication skills for my project.	4	4.75 (0.50)	6	3.33 (1.37)	12	4.08 (0.79)
I feel I had adequate time management skills for my project.	4	4.25 (0.96)	6	3.17 (0.75)	12	3.92 (1.16)
I feel I had adequate technical/programming skills for my project	4	4.25 (0.96)	6	4.00 (0.89)	12	4.08 (0.79)
I feel I had adequate teamwork skills for my project	4	4.75 (0.50)	6	3.67 (1.03)	12	4.08 (0.79)

The group with applied research experience had the highest mean for each of the four questions, expressing confidence in their communications and teamwork skills in particular. The participants in this study who did not have experience rated themselves as being adequate in each of the four skills, with very similar results across communication, technical, and teamwork. The group with work experience rated themselves the lowest in each of the four measures, expressing only a slight trend towards feeling their skills were adequate. In all three groups, time management was identified as the skill they felt least adequate with, though in the research experienced group this was tied with technical skills. The feeling of time management skills being the weakest of the four was particularly pronounced in the group with work experience, with a mean of only 3.17.

4.2 Adequacy of Team Members' Critical Skills

Four Likert scale questions asked the participants to rate their team members' skills in each of the four areas. The results are displayed in table 2 below.

Table 2
Students' Views of the Adequacy of The Skills of Their Team Members, Divided by Experience

	Research Experience		Work Experience		No Experience	
Statement	*n*	*M* (*SD*)	*n*	*M* (*SD*)	*n*	*M* (*SD*)
I feel that the other members of my team had adequate communication skills.	4	4.00 (0.82)	6	4.17 (0.41)	12	3.58 (1.51)
I feel that the other members of my team had adequate time management skills.	4	3.75 (0.96)	6	3.83 (0.41)	12	3.50 (1.51)
I feel that the other members of my team had adequate technical/programming skills.	4	4.25 (0.50)	6	4.17 (0.75)	12	4.00 (0.95)
I feel that the other members of my team had adequate teamwork skills.	4	3.50 (1.00)	6	3.67 (0.52)	12	3.67 (1.44)

The means for the three groups are relatively close together for these questions. The participants generally expressed satisfaction with the skills of their team members. Of the four skills the participants were asked about, each group rated the technical skills of their team members highest.

The participants who had work experience generally rated the skills of their team members above their own (see Table 1). With the exception of technical skills, the other two groups rated their team members' skills as less adequate than their own.

4.3 Preparation in Critical Skills

Likert questions. Five Likert scale questions were used in examining participants' views of how prepared they were in each of the four skill areas. Four of these questions are the same ones used to examine whether the participants felt their skills in each of the four areas were adequate for their capstone project (see table 1 above), while the fifth explicitly asked them if they felt their courses had prepared them for the project (see table 3 below).

The participants who had experience, whether from applied research or from work or co-op, gave answers that indicated they did not feel their courses had prepared them for their capstone projects, having means of 3.50 and 3.33 respectively. The mean of the group with no experience was very similar to the means on questions regarding their own skills in each of the four identified areas.

Table 3
Students' Views of Their Preparation for a Capstone Project, Divided by Experience

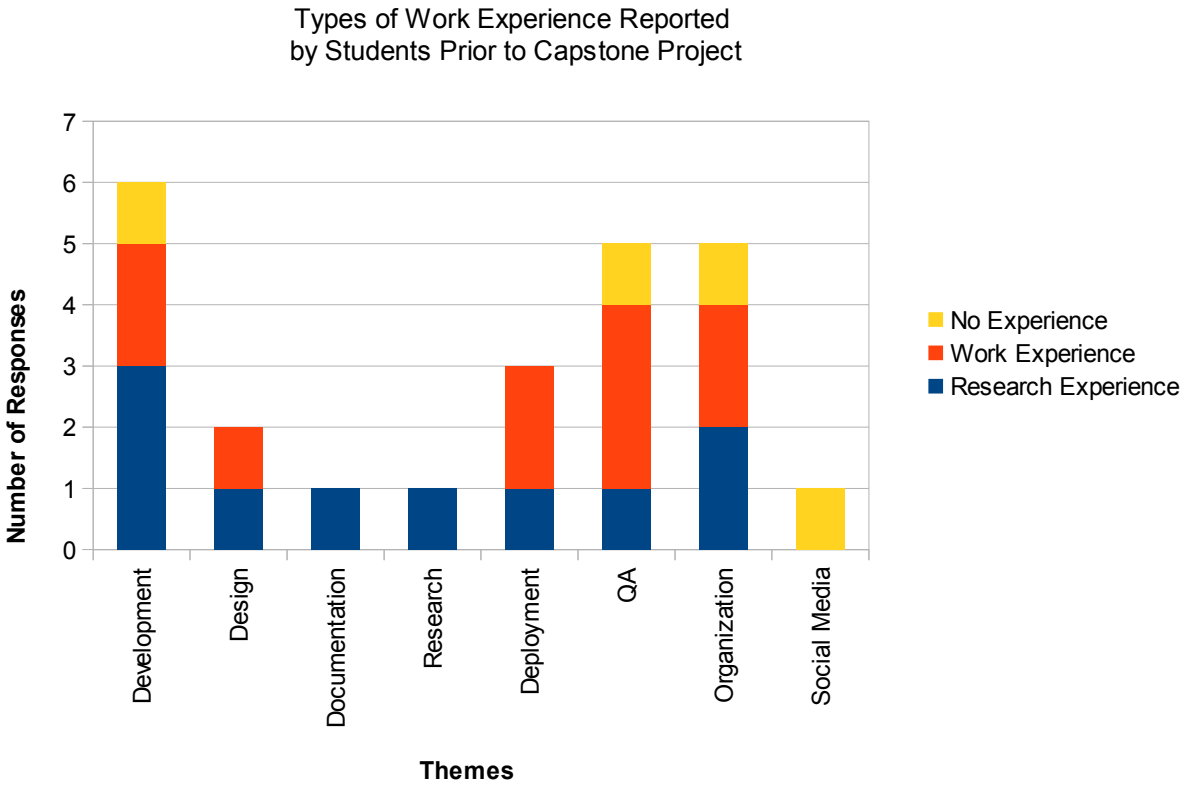
	Research Experience		Work Experience		No Experience	
Statement	*n*	*M* (*SD*)	*n*	*M* (*SD*)	*n*	*M* (*SD*)
I feel I had adequate communication skills for my project.	4	4.75 (0.50)	6	3.33 (1.37)	12	4.08 (0.79)
I feel I had adequate time management skills for my project.	4	4.25 (0.96)	6	3.17 (0.75)	12	3.92 (1.16)
I feel I had adequate technical/programming skills for my project	4	4.25 (0.96)	6	4.00 (0.89)	12	4.08 (0.79)
I feel I had adequate teamwork skills for my project	4	4.75 (0.50)	6	3.67 (1.03)	12	4.08 (0.79)
I feel that the courses I took adequately prepared me for my project	4	3.50 (0.58)	6	3.33 (0.82)	12	4.08 (0.67)

Open–ended questions. Three open ended questions were used to provide more information about what experiences (work or otherwise) participants had that they felt was relevant to their project, and what they would advise students starting their capstone (i.e., preparation they felt was lacking).

ICT work experience. Eleven participants provided answers to the question regarding ICT work experience (question 8 in Appendix A), including three who had not identified themselves as having any prior experience. These answers ranged for very concise (e.g., "Yes, QA" [Quality assurance]) to descriptions of common tools, operating systems, and software packages they worked with. Coding the answers to this question produced 24 separate statements which were broken into 8 themes (See Figure 1 below) regarding different aspects of ICT related work.

The work experience described by the participants with applied research experience was noticeably different from that reported by those with other work experience or co-op terms. While participants from the group with work experience described work focused on a single area (e.g., “System maintenance of SAP systems”, “design front end of website”), those who had applied research experience reported tasks from a variety of phases of researching, designing, developing, and maintaining software (e.g., “I have experience at **** working on a project where we designed, built, and developed a software system”).

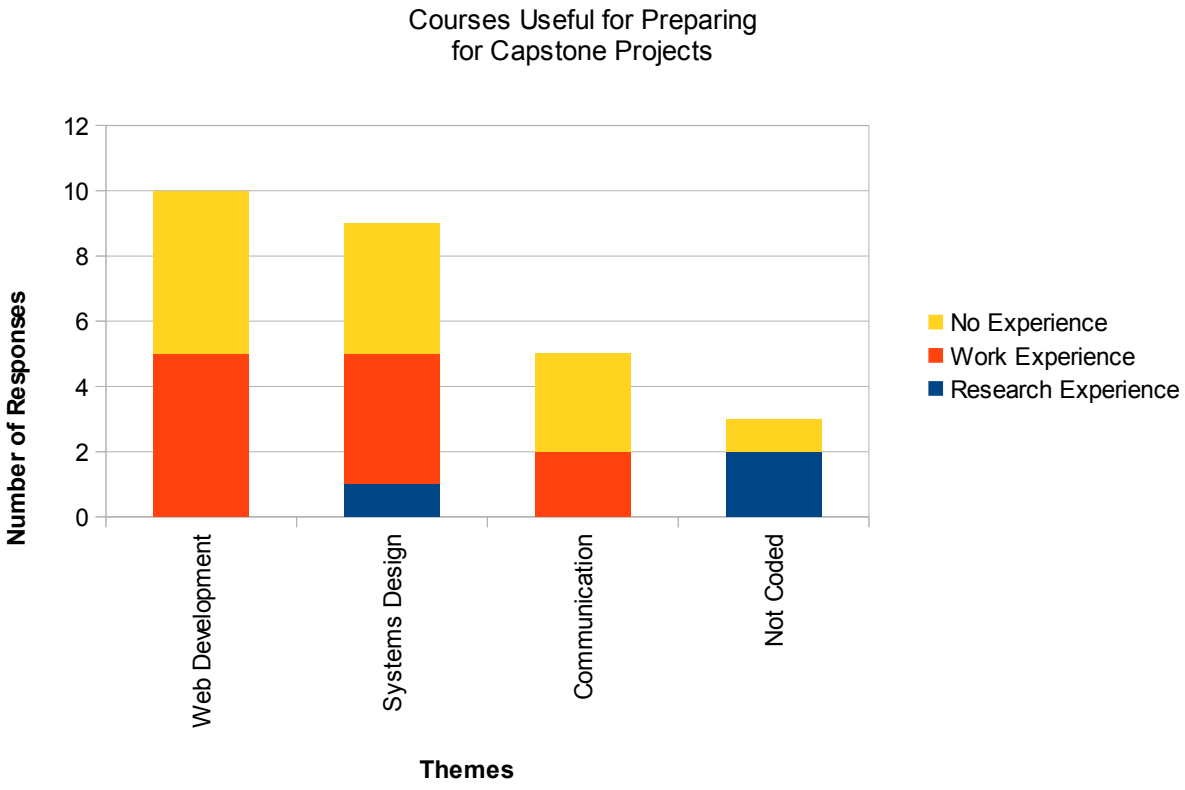
Figure 1



Other preparatory factors. Nineteen participants answered the question regarding other factors that had prepared them for their capstone project (question 9 in Appendix A), providing

26 separate statements. The statements were divided into five themes, with three statements left over (see Figure 2) as they did not provide information that would allow them to be included in an existing theme, and did not contain enough information themselves to create a new theme (e.g., one participants' answer was "Course. Only one course.", but they did not identify which course they were referring to). The majority of the answers to this question were related to two themes: a web-programming course, and a group of three courses related to system design (which includes the first half of the capstone project course).

Figure 2



A large portion of the responses to question 9 mentioned web-programming courses as being particularly useful in preparing for a capstone project. An important factor when

considering this information is that each of the projects developed by the participants in this study included some form of web interface.

A similarly large portion of the answers to question 9 dealt with a set of systems design courses which are intended to prepare students for the process of designing and implementing complete software applications. As such it is not surprising that such a large number of statements made reference to them.

Of the remaining answers, five were related to communication and collaboration. For example, three referred to collaboration and code-management tools (e.g., GIT, Google Docs). One participant referred to a multi-media presentation course, and one cited "client facing experience from work".

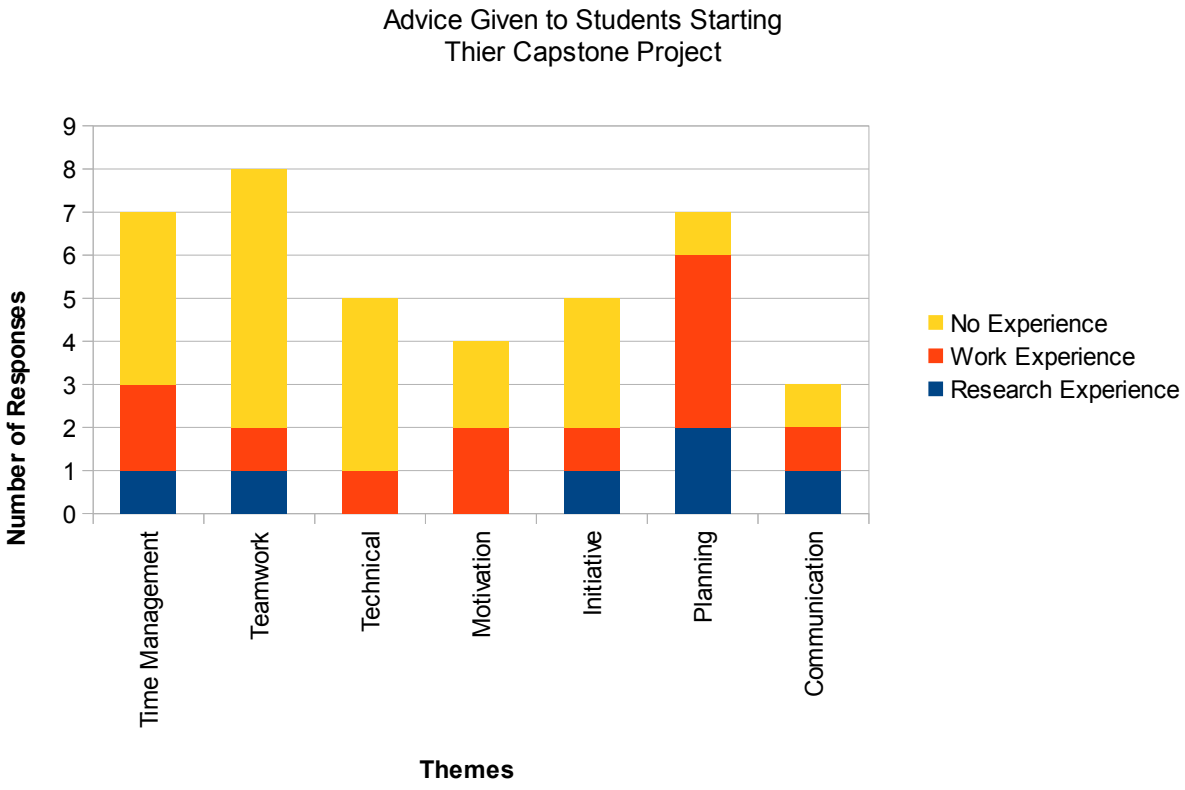
The participants with applied research experience provided very few answers for question 9 (three out of 26), and only one of those answers fell into the identifiable themes (e.g., "The two prior [systems design] courses gave me the basic background knowledge needed to complete my project"). Of the remaining two answers they gave, one credited the applied research work they had done, and the other gave credit to a variety of sources (e.g., "Previously taken courses at another institution. Working at a bank for a coop work term prior to joining this school"). This exposed a potentially compounding issue, as it revealed applied research experience may not be the only experience the participants from that group had.

Advice for future students. All 22 participants provided answers to the question regarding advice they would give a student starting their capstone (question 10 in Appendix A), producing 39 codable statements. The participants' answers fell into seven themes (see figure 3 below), four of which matched the skill areas already identified (team work, time management,

communication, and technical/programming). The additional themes identified were planning, motivation, and initiative.

The participants suggested that proper management of time is essential for success, providing advice such as "Time management is one of the most important things. Make a plan and follow it without any procrastinations.", and "Budgeting your time effectively is key to not being rushed at the end."

Figure 3



Participants also advised that team formation and management is equally important. Statements ranged from terse directives (e.g., "Choose team carefully", "Pick a good team"), to suggestions on allocating work within the team (e.g., "Make good connection inside team to

understand each member's strength and weaknesses", and "Get to know your team members and their working habits"). While most of the themes were split relatively evenly between the participants who had no experience those who had work experience, the majority of the answers that fell into this theme came from the non-experienced group.

Several participants suggested that finding projects they found interesting helped them keep motivated to complete it (e.g., "Try finding a project you're enthusiastic about", and "Make sure to pick something that you are interested in, so you will be motivated to work on it"), and that it was up to the students to keep themselves working (e.g., "Be prepared to take initiative to achieve success").

Some participants advised that planning work in advance would help avoid complications when implementing their design (e.g., "Focus more on planning in the initial stages to avoid dead ends"). The majority of the answers that fell into this theme came from the participants with work experience.

A small number of participants also identified communication between the team members and the client as important (e.g., "I would tell them to get a client they can talk to a lot and make sure they have a good team").

While the participants without experience gave a variety of answers relating to picking specific programming languages or tools (e.g., "Pick a programming language you/majority of the team is experienced with", "Know as many programming languages as possible."), the participants with work experience gave only one response that fit this theme and the participants with applied research experience did not provide any answers that fit this theme.

4.4 Importance of Critical Skills

Likert questions. Participants rated how important they felt each of the four skills (communication, time management, technical/programming, and teamwork) had been in their project, the results of which are summarized in table 4 below.

Table 4
Students' Views of the Importance of Skills, Divided by Experience

	Research Experience		Work Experience		No Experience	
Statement	*n*	*M* (*SD*)	*n*	*M* (*SD*)	*n*	*M* (*SD*)
Communication skills were important to my project	4	4.75 (0.50)	6	4.67 (0.52)	12	4.33 (0.65)
Time management skills were important to my project	4	5.00 (0.00)	6	4.83 (0.41)	12	4.58 (0.51)
Technical/ programming skills were important to my project	4	4.50 (0.58)	6	4.17 (0.75)	12	4.42 (0.67)
Teamwork skills were important to my project	4	5.00 (0.00)	6	4.67 (0.52)	12	4.33 (0.78)

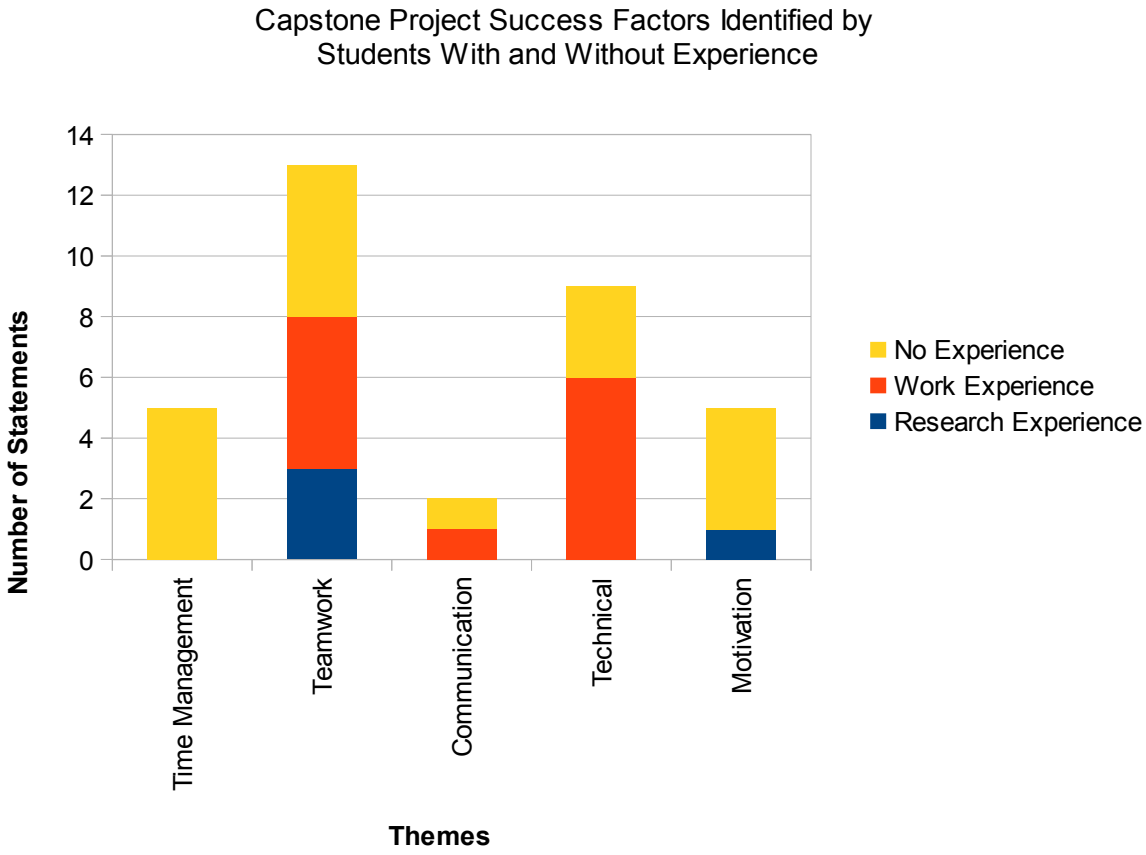
Overall, the participants indicated that they felt each of the four identified skills was important to their project, with the means of the responses from all participants combined being between 4 ('agree') and 5 ('strongly agree'), and only the importance of technical skills having an overall mean below 4.5. Of the 88 Likert responses measuring participants' views of the importance of the skills, only 4 of the responses were 3 ('neither disagree nor agree'), and no responses indicated that the skills were unimportant. The participants with applied research experience indicated that they felt time management and teamwork were particularly important, as all the participants in that group responded with 5 ('strongly agree') for the importance of both of those skills.

Participants elaborated on any other factors they felt had been important to the success or failure of their project (question 12 in Appendix A), and anything that had helped them prepare for their capstone (question 13 in Appendix A).

Factors important to project success. Twenty participants provided answers to question 12, producing 34 statements. In addition to the four expected themes based on the skills already

identified (time management, teamwork, communication, and technical skills), participants' answers produced a fifth theme of motivation as having a significant impact on project success (See Figure 4).

Figure 4



Five of the answers given by the participants suggested that effective time management was essential, though some of these statements also included information coded into other themes: "Time management and technical skills are really important to succeed in the project".

The largest theme produced by answers to this question was that teamwork was essential to project success. Participants, regardless of experience, expressed that a functional team had

been very effective (e.g., “I was successful because of the team’s cooperation”, and “Good support from the other team members.”), or that members not acting as a team had interfered with or delayed the completion of the project (e.g., “Failure: unreliable team member.”). Participants also expressed benefiting from the varied skills and experience their teammates had (e.g., “Other team members had actual work experience”).

The smallest theme generated by this question (two statements) was communication (e.g., “Communicating with team members was essential to success”). The small number of participants whose answers included communication was unexpected, as they rated it approximately in the middle of the other skills in terms of it importance, and their capabilities.

A number of participants identified programming languages or tools as being important to their project (e.g., “Prior experience with programming languages”, and “JavaScript course would be helpful”). Despite this being the second largest theme created by the answers to this question, none of the answers from participants with applied programming experience fit this theme.

The final theme generated by this question was that motivation was important to the success of the project. Participants, particularly the older ones, expressed feeling strong motivation to succeed (e.g., “I knew from the beginning with or without my team cooperation I will make everything possible to succeed”, or “My team was very dedicated and passionate about the whole project”).

Preparation important to project success. The results of question 13 have already been discussed above as participants’ answers to it were used to examine their views of the important skills in addition to things they felt they had been helpful in preparing them for their project. The answers were examined for this research question as well, as it was expected that some of the

answers given would relate to the identified critical skills. As expected, many of the responses to this question were related to technical skills, noting web-programming courses as being helpful and five responses were related to communication & collaboration. As noted above, none of the responses related to the identified skills were from participants who had applied research experience.

4.5 Satisfaction with Capstone Project

Likert questions. Three Likert scale questions were used to examine participants' satisfaction with their capstone project and the work they had done for it (the results of which are summarized in Table 5) along with one open ended question regarding why they were satisfied or dissatisfied (question 15 in Appendix A).

Table 5
Students' Satisfaction With Their Capstone Project, Divided by Experience

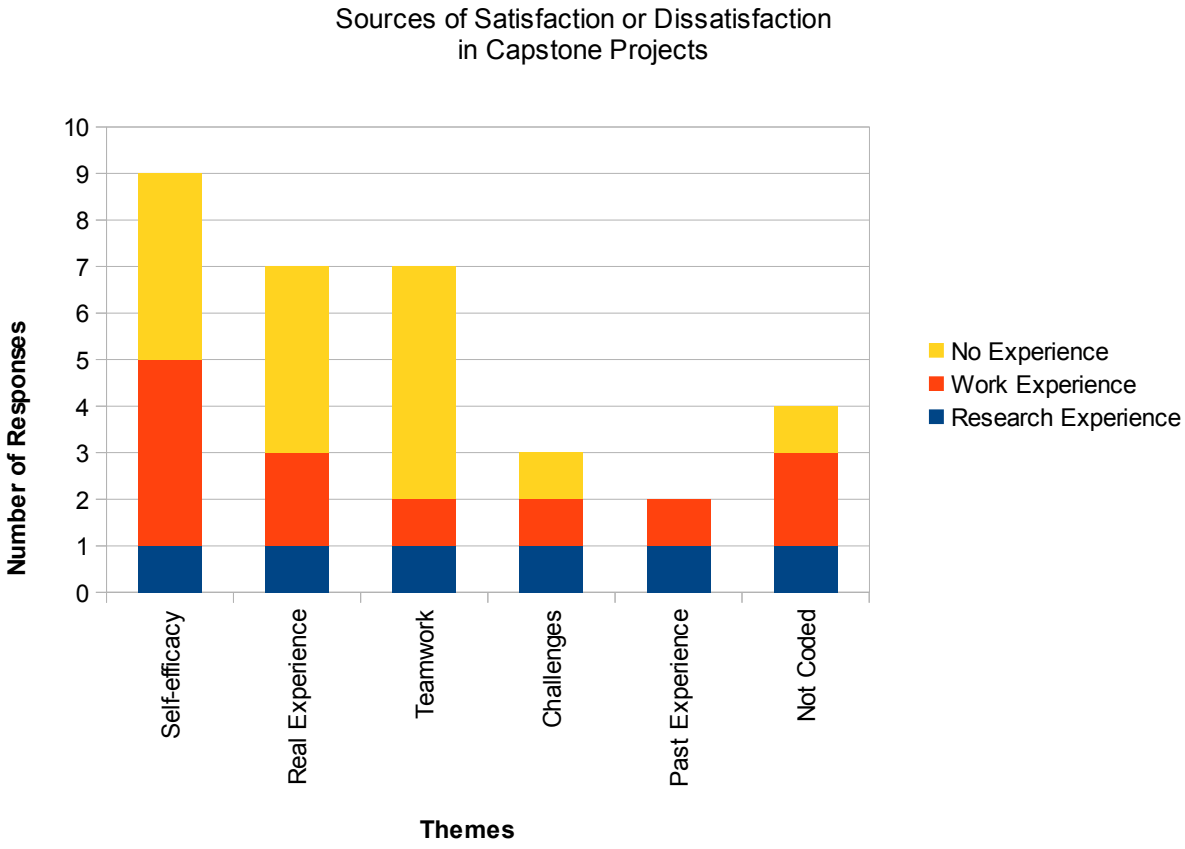
	Research Experience		Work Experience		No Experience	
Statement	*n*	*M* (*SD*)	*n*	*M* (*SD*)	*n*	*M* (*SD*)
I am satisfied with my work on this project	4	3.75 (0.50)	6	3.50 (1.05)	12	4.17 (0.58)
I feel that this project accurately reflects my abilities	4	2.75 (0.50)	6	3.00 (0.89)	12	3.75 (1.14)
My project was a success	4	4.25 (0.50)	6	3.50 (1.05)	12	4.42 (0.51)

The results to two of these questions ('I am satisfied with my work on this project' and 'my project was a success') did indicate general agreement with the statements, with overall means of 3.91 and 4.14 respectively, however the results of the third question ('I feel that this project accurately reflects my abilities') produced the lowest overall mean of any of the Likert scale questions ($M = 3.36$, $SD = 1.05$). While the participants with no experience responded that they felt the project was an accurate representation of their abilities ($M = 3.75$, $SD = 1.14$), the participants with work or co-op experience did not agree or disagree ($M = 3.00$, $SD = 0.89$), and the participants with applied research experience disagreed slightly, with the only mean in the study below 3 ($M = 2.75$, $SD = 0.50$). This suggests that the participants who had any form of

experience prior to their capstone projects did not feel the project properly represented their capabilities, even when they considered the project a success.

Open-ended question. All 22 of the participants provided answers to question 15, creating 28 codable statements, which were divided into themes of self-efficacy, real experience and teamwork, challenges, and past experience (See Figure 5). Four statements were not added to these themes, as they expressed satisfaction (e.g., "Somewhat satisfied"), but did not provide any additional information necessary to establish them in a theme.

Figure 5



The largest theme generated by this question was one of self-efficacy. Nine of the participants expressed pride and satisfaction in their accomplishments (e.g., “Very satisfied. I took an idea I had and turned it into something real”, and “I am satisfied. I learned how to start from scratch and build a fully functional project”).

Six participants, three of who were from the oldest age-bracket, identified working with a real client as a factor in their views of success (e.g., “Very satisfied! The project gave me experience of communicating with a real client”, and “Gained work experience I could add to my resume”). In the final statement that fit this theme, one of the participants expressed dissatisfaction over conflicts of interest between their team and the project client.

The third major theme identified was the teamwork experience gathered through the project. Answers that fit this theme were split almost evenly (three to four) between expressing dissatisfaction because the team had not worked well together (e.g., “No. MY TEAM WAS POOR” [emphasis in original]), and feeling satisfied because the team had been effective (e.g., “I was very satisfied, because all three of us were very different and it made our team stronger in terms of diversity of tasks we can implement”).

Three answers related feelings of satisfaction to overcoming stress or logistical issues during the project (e.g., “It was stressful but in the end I was satisfied with the outcome”). The statements that fit this theme were evenly distributed between the three participant groups.

The final theme identified was a relation of past experiences to levels of satisfaction (e.g., “If I didn’t have my **** previous experience I would have said I was satisfied, but my [project] course was much more poorly organized”). One statement for this theme came from each of the two experienced participant groups.

4.6 Satisfaction with Team Members

Likert questions. Three Likert scale questions were used to examine participants' satisfaction with their team members and the work they had done for it, the results of which are summarized in Table 6, along with one open ended question regarding why they were satisfied or dissatisfied (question 17 in Appendix A).

Table 6
Students' Satisfaction With Their Capstone Project Team Members, Divided by Experience

	Research Experience		Work Experience		No Experience	
Statement	*n*	*M* (*SD*)	*n*	*M* (*SD*)	*n*	*M* (*SD*)
I am satisfied with my work on this project	4	3.75 (0.50)	6	3.50 (1.05)	12	4.17 (0.58)
I am satisfied with the work of my team members on this project	4	4.00 (1.41)	6	3.83 (0.98)	12	4.08 (1.00)
Given the opportunity I would willingly work with my team members again	4	3.50 (1.29)	5	3.60 (1.52)	12	3.58 (1.56)

Participants generally expressed moderate satisfaction with their project, and with their team members, with similar means between the groups, particularly for satisfaction with team members. The responses to the question regarding being willing to work with team members on future projects were particularly noteworthy. The mean and standard deviation for each of the three groups were very similar, the closest of any of the Likert scale questions used in this study.

Open-ended question. The results of the open ended question used to examine participants' satisfaction with their team members have already been described as it is the same question used to examine participants' satisfaction with their own work (see Figure 5). The responses were included in analyzing this research question as it was expected that teamwork would be integrally related to students' satisfaction with their project. As noted above, the participants' responses revealed a connection with their satisfaction with their team members and satisfaction with the project as a whole.

5 Discussion

5.1 Overview

The participants' responses to several of the survey questions revealed noticeable differences between the participants with experience and those without. Of particular interest are the results that suggested the participants with applied research experience expressed feeling more capable of effective teamwork and communication, and were less concerned with the minutia of specific programming languages or tools than their peers who did not have applied research experience. However, prior to discussing the answers to the research questions, several potential areas of bias must be examined.

5.2 Potential for Bias

First, the limited number of female participants in the study could have indicated a bias in the sample, or a problem with the data gathering techniques; however the majority of the students in both programs are traditionally male. While the uneven split between genders limits the generalizability of these findings to other programs, it was expected based on the population being studied.

Second, there was a potential for some bias towards feelings of success to be found in this study. While the original attempt to gather data was made just after the participants completed their projects and before they had received grades, the low response rate necessitated a second attempt after the end of the course. This limited participants in the second data-gathering attempt to only those who had passed the capstone project course in the degree. However, the same number of potential participants were present in the class as had been on the email list for the degree program in the initial attempt. While it can not be said with absolute certainty that they were the same students, the small size and cohort-based nature of the program

makes it very likely that they were. As such, it would appear that the majority of the participants in this study passed their capstone courses, and may have had a bias towards viewing their project as a success.

The imbalance in response rates between the two programs biases the results towards participants from the degree program. While the initial attempt to gather data included a large number of students from two capstone courses in the diploma program, they were not available for the second attempt to gather data. The capstone course for the diploma program occurs in the final semester, so the students who had been in course that had been selected would have graduated, and were unavailable for the second attempt at contact.

Not having a second rater prevented obtaining a measure of inter-rater reliability for the qualitative data. Due to this there is a potential for misinterpretation or confirmation bias in the discussion of the participants responses to the open ended questions.

Finally, the very small sample size raised several issues with the statistical analyses that were originally intended. These results do not indicate a definite difference between the groups. Instead the results illuminate areas for future research.

5.3 Perceptions of Personal Skill Level

The participants who had no experience and those with applied research experience expressed feeling that their skills in each of the four areas were adequate for their project. On the contrary, participants who had experience either through employment or co-op courses generally rated their skills as only barely adequate. In particular, the participants with work experience rated their time management skills as neither adequate, nor inadequate ($M = 3.17$, $SD = 0.75$).

In each of the four skill areas the participants with research experience rated their skills higher than the other participant groups did, especially in communication and teamwork. This is consistent with earlier research that found PBL to be effective in developing students' ability to apply their knowledge to unfamiliar situations and their ability to work in a team (Dochy et al., 2003; Savery, 2006). There is insufficient data from this study to confidently suggest that applied research experience was the cause of these participants' perceptions of elevated capability with any of the critical skills, but the apparent difference makes this a promising area for future research.

Contrary to this result, the participants with work experience rated themselves lower in each skill area than the participants with no experience did. This difference was particularly pronounced in time management and communication. As these participants were the ones who had the experience that capstone projects are intended to prepare students for, these results were unexpected. The answers given were the participants' perceptions of their own skills, so it is possible that this group simply held themselves to a higher standard. A second possible explanation for this unexpected finding would be if these participants were continuing to work during their capstone projects there would be more demands on their communication and time management skills. Again the current data and sample size are insufficient to support stating there is a significant relationship between work experience and feeling less confident with the key skills, but any further investigation in this area should include questions relating to why students rate their skills they way they do.

5.4 Perceptions of Team Members' Skills

While the participants in this study rated their team members' skill levels similarly regardless of the experience they had, comparing the ratings of team members' skills with ratings

of personal skills revealed another potentially interesting area of study. The participants who had work experience rated their team members' skills higher than their own, while the participants with applied research experience rated their team members' skills as less adequate than their own. It is possible that the observed difference is simply a side effect of how the two groups rated their own skills. That is, they rated their team members the same and there only appears to be a difference because of the difference in how participants with work experience and those with research experience rated themselves. A second possibility is that the participants who rated themselves as having strong skills worked with participants with less developed skills. Even with the small sample size having all groups have that structure seems unlikely. Additionally, that possibility would depend on the participants' rating of their skills being close to their members ratings of their skills. This study did not gather data on the structure of the groups, so it is not possible to determine what experience each participant's team members had.

While it was not initially intended that the answers to the open-ended questions be used to answer this research question, a significant number of the participants' answers to the open ended questions (28 of 154 statements) fell into a theme of team skills. This finding suggested that the abilities of team members and the ability of the group to coordinate their efforts were a significant concern to the participants, regardless of prior experience. Considering how prevalent team work is in the literature on capstone courses (e.g., Pilskalns, 2009; Stein, 2003; Zhang & Wang, 2011) and on PBL (e.g., Barrows, 1986; Dahlgren & Dahlgren, 2002; Dunlap, 2005), it is unsurprising that the skills of the team and the ability of the members to work together effectively was such a significant concern for the participants in this study.

The identified importance of team work in capstone projects (Grant et al., 2010; Ikonen & Kurhila, 2009; Keogh et al., 2007) suggests that the potential relationship between

participants' experience, their perceptions of their skills, and those of their team members requires further study.

5.5 Perceptions of Preparedness

A comparison of the responses to the five questions revealed a potential difference between the views of the participants who had work experience or no experience and the participants who had applied research experience. The participants from the work experience group and the inexperienced group rated the preparatory value of their courses similarly to how they rated the adequacy of their skills. The work experienced and non-experienced groups also gave a variety of answers to the open ended questions that made reference to courses as being useful preparation for their capstones, though most of those responses were related to the development of technical skills and only a five responses were related to communication and collaboration skills. This is generally consistent with the findings in the literature that typical courses developed students' technical skills, but left them with underdeveloped 'soft' skills (Keller, 2011; Pilskalns, 2009; Stein, 2003; Venables, 2009; Zhang, 2011).

The research experience group expressed feeling very capable with the key skills yet they rated the preparatory value of their courses somewhat lower than the other participants. Only one of the few open ended responses the participants with applied research experience gave for this question made any reference to course work. While there is not enough data to confidently state that the applied research experience was responsible for this groups' feelings of preparedness, research on PBL suggests that an environment like the applied research work should help students develop the skills needed for a successful capstone project (Barrows, 1986; Dunlap, 2005; Savery, 2006; Savery & Duffy, 2001).

Within 6 of the 7 themes generated by the participants' responses to question 10 ('If you could give any advice to a student about to begin his/her capstone project, what would you tell them?'), the participants with applied research experience gave similar answers to the rest of the participants and were represented at a rate roughly in line with their population-size compared with the sample population (18%). However, the theme of programming/technical skills displayed a division between participants who had applied research work and those who did not. Due to the small sample size, this would not be particularly unusual; however none of the answers given by the participants with applied research experience for any of the five open-ended questions fell into a technical theme. This result combined with the research experienced group rating technical skills as the least important of the four skills (with a mean of 4.50, compared to 4.75 for communications and 5.00 for and teamwork and time management) suggests that the participants with applied research experience may have been less concerned with the particular tools used to complete the project than the other participants were. The applied research experienced groups' views that technical skill is important, but not any one specific technology may indicate they had developed the general technical adaptability that research on capstone projects has found many students lack (Keogh et al., 2007; Umphress et al., 2002) If this is the case, it would suggest a potential benefit of applied research experience that would assist students in their capstone courses and future employment.

5.6 Perceptions of Important Skills

The participants rating each of the identified skills as important to their projects was expected based on the results from previous research (Keller et al., 2011; Lynch et al., 2004; Zhang & Wang, 2011). Both of the experienced groups rating of technical skills as being slightly less important than the other skills was also consistent with the findings from other studies on

capstone projects (Ikonen & Kurhila, 2009; Stein, 2003; Umphress et al., 2002; Venables & Tan, 2009; Zhang & Wang, 2011).

The responses to the open ended questions revealed a distinct difference between the views of the applied research experience group and the other participants. While the non-experienced and work experienced groups gave a variety of answers relating to specific technologies as being important, none of the answers given by the participants with applied research experience for any of the open ended questions were related to technology. Given that the applied research group rated technological skills as quite important to their project ($M = 4.50$, $SD = 0.58$) it was unexpected that it would be so conspicuously absent from their responses to the open ended questions. It is possible that this indicates a concern with general technical adaptability over ability with any specific tool or programming language, however there is insufficient data from this study to determine if this is the case. Research on capstone projects suggests that many students lack general problem-solving and technical flexibility (Keogh et al., 2007; Umphress et al., 2002), so the possibility that applied research experience may support the development of these skills bears further investigation.

5.7 Student Satisfaction with Capstone Project

The participants who had any form of experience were less likely to express that their project was an accurate representation of their abilities. One third of the participants with work experience, and three of the four participants with applied research experience disagreed with the statement that the project was an accurate reflection of their abilities. Analysis of the participants' responses to the question asking them to elaborate on why they were satisfied with their project did not reveal any indication as to why this was, and many of those who felt the project did not reflect their abilities still viewed their project as a success. The fact that the

majority of participants felt their project was a success may have been influenced by the data gathering methods. The initial survey was given before the students knew their marks, but the in-class survey was given early in the next semester so any participant who responded to it had to have passed their capstone project course. It seems reasonable to expect that most students who passed the course would view their project as a success.

The dissatisfaction expressed by the experienced students was related in their open ended responses to awareness that the project could have been better. While motivation from creating realistic work is noted in the literature (Barrows, 1986; Pilskalns, 2009), it appears that the participants who had experience developing real applications experienced dissatisfaction when the work of their team members did not meet their expectations.

The answers that participants gave to question 10 (Please describe whether or not you are satisfied with your experience in your capstone project and why) also revealed an unexpected difference between the older participants and the younger ones. The participants from the older age bracket (31 to 40) were more likely to express viewing the experience gained as being useful for their future (e.g., “I am pretty sure without this project I would not succeed in coop”), even when they already had ICT work experience (e.g., “Gained work experience I could add to my resume”), a view which is strongly linked to motivation in capstone projects and PBL (Barrows, 1986; Pilskalns, 2009).

The importance that participants placed on teamwork when considering their satisfaction with their project supports the suggestion of further research into things that can develop students’ teamwork skills prior to beginning the project.

5.8 Satisfaction with Team Member Work

The participants' responses to the four questions related to satisfaction with their team members suggested that past experience may not play a role in a participants' satisfaction with their team members. The responses of each group to questions 16b and 16c had very similar means.

Unsurprisingly, participants' who rated their team members' skills highly where likely to express satisfaction with their team members and to be willing to work with those team members on future projects. While the sample size was too small to reliably determine if there was a statistically significant relationship, the open ended responses supported the possibility. Statements of satisfaction or dissatisfaction were commonly linked directly to statements of the quality of the participants' team (e.g., "I am mildly satisfied with the capstone project because I think our group could have done an even better job"). This suggests that the participants' perceptions of their team members was related to their satisfaction with their project, and reinforces the findings discussed above that the participants viewed teamwork as a very important skill in their capstone projects. It is also consistent with the findings of earlier studies on the importance or teamwork in capstone projects (Ikonen & Kurhila, 2009; Keogh et al., 2007; Keller et al., 2011; Lynch et al., 2004; Zhang & Wang, 2011).

The analysis of this research question suggests that the participants' past experiences did not have an effect on their satisfaction with their team members, however there is no information on whether the experience the team members had has any impact on satisfaction with their work or the project. As noted in the research question regarding perceptions of team members' skills, this requires further study.

6 Summary and Conclusions

6.1 Overview

This study suggests that there may be some differences between participants with different types of experience prior to participating in their capstone project course. The participants who had applied research experience expressed feeling more prepared for their capstone projects and more capable than their team members. The participants with work experience reported the opposite, viewing themselves as less prepared and less capable than their team members. Neither of the experienced groups credited their courses as being particularly helpful in preparing for their project and tended to be more concerned with the application of soft-skills than with individual technologies while the non-experienced group rated the preparatory value of their courses as equal with their skills. While the data available is not sufficient to suggest the participants' past experiences caused this difference, or even to confirm that there are any differences, it does hint at a possible relationship between students experiences outside courses and their perceptions of their skills.

6.2 Limitations

The small sample size and the relatively homogeneous nature of the sample severely limit the reliability and validity of these findings. The homogeneity is not as significant an issue as it might be in other studies, as the demographics of the sample closely match the school population from which it was drawn, however the school population in this study may not match those of other schools. Regardless, the small sample size prevented the initially intended statistical analysis. Instead this study is designed to inform areas of interest for further research.

The participants who responded to this study give a good representation of the students in the degree capstone course with a response rate greater than 90%. However the image of the

diploma students is much less reliable with less than a 5% response rate. This difference is linked to the tools used to gather the data. The diploma students were only contacted through email for the web-based survey, while the degree students were later contacted again, in class, and asked to fill out the paper survey. It would be prudent to use in-person contact for any further research drawing participants from this population.

The very small number of participants with applied research experience also presents issues in studying this population. The research department only employs a small number of students each year, and only a few of those would be completing their capstone project at any one time. In order to mitigate the small population available in the courses studied, further research in this area would be well advised to examine several cohorts passing through their capstone courses. This would build up a more substantial pool of potential participants, particularly those with applied research experience, which should produce more statistically reliable data.

The responses to questions regarding previous experience revealed a potential issue with considering the participants who had applied research experience as a single group. One participant gave answers suggesting he had also had other work experience unrelated to applied research. While this participant gave responses that were similar to the others who had applied research experience, a more detailed more examination of work experience bears close examination in any future research. A similar issue was noted with three students who identified in question 4 as having no related work experience, but provided answers to question 8 describing work experiences. Using interviews instead of surveys in future research involving this population would allow for deeper exploration and clarification of participants prior experiences.

The design of the survey may have had an impact on the themes that emerged in the open-ended questions. As participants completed the Likert scales first, the four pre-identified skills could have had an effect on the answers they gave to the open-ended questions. This may not be a significant issue, as the themes were drawn from the literature and the participants responses confirmed that they considered those themes important. However, it may have masked the emergence of other potential differences.

Finally, the absence second rater of open-ended responses limits the reliability of coding the responses to the open ended questions. Without being able to establish a measure of inter-rater reliability, it is impossible to say if the themes were skewed by potential bias on the part of the coder.

6.3 Future Research

This study found 6 potentially promising areas for future research. First, confirmation is needed as to whether students with applied research experience in general feel more capable than their peers and if so whether they really are more capable or just perceive themselves to be. There is also the unexpected discovery that students with work experience may feel less prepared than the other students. Gathering data from a larger sample would allow for proper statistical analysis to confirm or refute the possibility of past experience having an impact on students' perceptions of their abilities. Supporting a larger survey with interviews targeting the students who had any form of related experience outside of coursework would allow deeper exploration of the reasons behind the students' perceptions of their abilities. However, in order to be able to identify which participants had prior experience in order to contact them for interviews and to conduct those interviews participation could no longer be completely anonymous. Extra care would have to be taken to protect the participants' personal information.

If past experience is confirmed to have an impact on students' perceptions of their skills, it would lead to the second potential area for future research. Namely is the difference in abilities merely a difference in perception, or is it reflected in the quality of the students' work? Examining this could entail observing select groups in action, as students' behaviour during team meetings has been found to be a predictor of success (Loyens et al., 2013). Examination of the faculty and industry partner assessments of the students could also help to illuminate whether the potential differences are merely perceived or reflect actual skills.

The third area for future research would be to examine if past experiences impact how students are rated by their team members. The views of the participants in this study were consistent with the findings of other research (e.g., Ikonen & Kurhila, 2009; Pilskalns, 2009; Zhang & Wang, 2011) that teamwork and team structure were vitally important to project success. This could be explored in the same interventions described in the first area for future research. The identified survey could ask each participant to list their team members and to rate them as individuals instead of as a collective. The lists could be compared to those participants' responses to identify which ones had prior experience. Exploring the team structure in this manner would mean that the survey could no longer be completely anonymous however that has already been identified as a consideration in conducting that survey.

The fourth area for future research is to examine what made the participants who had applied research experience feel more prepared than their peers, and what made the participants with work experience feel less prepared. Neither group gave much credit to their coursework as being a significant factor in preparing them for their capstone projects. The targeted interviews already identified would allow further exploration of the students' views on this matter.

The fifth area of potential future research relates only to the students with applied research experience. While they expressed feeling that technical skills were important, unlike the other participants they did not provide much information on why. Assuming the survey was to confirm the existence of a differing view, the targeted interviews would allow for further discussion of details more specific than just 'technical skills'.

The final area for future research would be to examine why both experienced groups felt the project did not reflect their abilities. The data available in this study suggests that this may be linked to dissatisfaction with their team members, and this too could be explored in more detail in interviews targeting the students with any form of experience outside typical course work.

If the identified future research were to confirm that there are educational benefits to having applied research experience, a detailed examination of students' activities in the applied research environment would help determine what caused those changes so they could be integrated into earlier courses in order to better prepare all students for their capstone projects, future employment, and life-long learning.

Finally, this study indicated an unexpected result, in that older students were more likely to view the project they completed as a potential stepping-stone for employment, either with the client they had completed the project for, or simply as something to add to their resume. As the literature did identify this view as a significant motivational factor, the cause for this difference would also be a worthwhile subject of further study.

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Appendix A – Survey

Demographics

1. Gender (Male, Female)
2. Age (18-20, 20-25, 25-30, 30-40, 40-50, 50+)
3. Program (CPA,BSD)
4. Work experience prior to this project (Co-operative term, Applied research, Other, None)

Adequacy of critical skills

5. Please indicate your agreement or disagreement with the following statements. (Options were: Strongly Disagree, Disagree, Neither Disagree nor Agree, Agree, Strongly Agree)
    a. I feel I had adequate communication skills for my project
    b. I feel I had adequate time management skills for my project
    c. I feel I had adequate technical/programming skills for my project
    d. I feel I had adequate teamwork skills for my project

Adequacy of team member skills

6. Please indicate your agreement or disagreement with the following statements. (Options were: Strongly Disagree, Disagree, Neither Disagree nor Agree, Agree, Strongly Agree)
    a. I feel that the other members of my team had adequate communication skills
    b. I feel that the other members of my team had adequate time management skills
    c. I feel that the other members of my team had adequate technical/programming skills
    d. I feel that the other members of my team had adequate teamwork skills

Preparation in critical skills

7. Please indicate your agreement or disagreement with the following statements. (Options were: Strongly Disagree, Disagree, Neither Disagree nor Agree, Agree, Strongly Agree)
    a. I feel I had adequate communication skills for my project
    b. I feel I had adequate time management skills for my project
    c. I feel I had adequate technical/programming skills for my project
    d. I feel I had adequate teamwork skills for my project
    e. I feel that the courses I took adequately prepared me for my project
8. If you do have IT work experience outside of your coursework, please describe the types of tasks that you commonly performed.
9. Please describe any other factors (e.g., courses, other experiences) that were particularly useful in preparing you for your capstone project.
10. If you could give any advice to a student about to begin his/her capstone project, what would you tell them?

Importance of critical skills

11. Please indicate your agreement or disagreement with the following statements. (Options were: Strongly Disagree, Disagree, Neither Disagree nor Agree, Agree, Strongly Agree)
    a. Communication skills were important to my project
    b. Time management skills were important to my project
    c. Technical/programming skills were important to my project

    d. Teamwork skills were important to my project
12. Please describe any other factors that you felt were integral to the success or failure of your project.
13. Please describe any other factors (e.g., courses, other experiences) that were particularly useful in preparing you for your capstone project.

Satisfaction with capstone project

14. Please indicate your agreement or disagreement with the following statements. (Options were: Strongly Disagree, Disagree, Neither Disagree nor Agree, Agree, Strongly Agree)
    a. I am satisfied with my work on this project
    b. I feel that this project accurately reflects my abilities
    c. My project was a success
15. Please describe whether or not you are satisfied with your experience in your capstone project and why.

Satisfaction with team members

16. Please indicate your agreement or disagreement with the following statements. (Options were: Strongly Disagree, Disagree, Neither Disagree nor Agree, Agree, Strongly Agree)
    a. I am satisfied with my work on this project
    b. I am satisfied with the work of my team members on this project
    c. Given the opportunity I would willingly work with my team members again
17. Please describe whether or not you are satisfied with your experience in your capstone project and why.

Appendix B – Invitation Email

Dear Student,

Invitation

You are invited to participate in a research study currently being run at Seneca College. This email describes the purpose of the study, what participation will entail, and your rights as a participant should you chose to participate. The study is being conducted by Professor Peter Callaghan, school of Information and Communications Technology, Seneca College of Applied Arts and Technology.

Purpose of the Study

Several skills have been identified by employers and by the government of Ontario as essential to student success and employability. This study will examine how past experience affects student success and attitudes related to these skills as applied in project-based subjects, with the intent of integrating beneficial experiences into earlier subjects in order to improve future students' experiences at Seneca.

You have received this email because you are currently registered in such a subject and are invited to take part in the study.

Methodology

Participants will be asked to complete a web-based survey (approximately ten minutes in length) shortly after the end of the semester (The survey will be available from 00:01 on April 18th, until 23:55 on April 26th). The survey will be on the school's moodle server (https://open.senecac.on.ca/cms/) under the Winter 13 set of courses, listed as 'Research Survey'. In case you need further instructions for logging in or locating the survey a slide set has been prepared to guide you through the process and is available in pdf ppt and odp.

Right to Withdraw and Confidentiality

Participation in this study is entirely voluntary, and the identity of those who choose to participate will be kept anonymous. While entry into the survey will require a student login, any identifying information will be removed from the data upon completion of the survey. All survey data will be encrypted and password protected, accessible only by the researcher conducting the study.

As the survey will be run through the school's Moodle server, the Moodle administrator will be capable of accessing to the data, however no other professors or school administrative staff will have access to the data, and your responses will be removed from the server as soon as possible after the survey is complete. No record will be kept of who participated and who did not. The choice to participate and the answers you give will not affect your grades or any other form of assessment.

You are free to withdraw at any time up until submitting the completed survey. If you do so, no data will be stored. Once the survey is complete, any identifying information will be removed, therefore it will be very unlikely that individual participant's data will be identifiable after that time.

Publication of Results

Data obtained through this survey may be published or presented at conferences. Once again, all data will be kept anonymous and will not be linked back to any individual participant.

Questions

If you have any questions about the study, you may contact the researcher through email: peter.callaghan@senecacollege.ca or by phone at 416-491-5050 ext 33173. If you have questions about your rights as a participant, contact Seneca's research ethics board at REB.Chair@senecacollege.ca. This study has been reviewed and accepted by the research ethics boards of Seneca College (reference #13-02) and the University of Ontario, Institute of Technology (reference #12-092).

Thank you for your time,

Peter Callaghan