The impact of learner-controlled blended instruction
on academic achievement:
A mixed method exploratory case study

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ABSTRACT

The impact of learner-controlled blended instruction on academic achievement:

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To date blended learning designs for university courses range from complementing the face-to-face class experience to replacing parts of the face-to-face contact time with online modules. The design is usually set by the instructor and/or instructional designer of the course and all students use the prescribed model. In introductory courses, typically first year courses, students' prior knowledge of the course topic range from limited to substantial, especially in a computer programming course. Having all students in such a course confined to the same course structure is unlikely to respond to differential student needs. The design proposed and studied in this research paper thus deviates from this approach. The face-to-face course was supplemented by lecture capture and a number of learning objects available online for students to use whenever and wherever they want. Students chose to attend or not attend classes, and chose which online tools to use and when. That is, they could switch throughout the term between being a face-to-face student or a blended/hybrid student based on their varying learning needs at different points in the term. They only needed to be present for summative evaluations.

The study was exploratory in nature, looking at the relationship between students' attendance records and their use of the online learning tools with their performance on summative evaluations. By examining the most successful usage patterns, the goal was to establish guidelines for students on how to best study in an introductory computer programming course.

The results showed that the attendance was not greatly affected by the availability of the lecture capture and learning tools online. Students initially used the online tools to supplement the in-class experience but not to replace it. Of the resources available online, the most popular was the lecture capture (a passive information tool) followed by the formative evaluation quizzes (an active cognitive tool). Students' usage pattern of the tools changed during the term. Most students started off as a predominantly face-to-face student but many switched to being hybrid or blended learners. Many students never used the online environment and remained face-to-face learners. Of those who did use the online tools, three usage patterns emerged: the distributed user, the massed user and the one-time user. Results show that the distributed user significantly outperformed the massed users. The non-users, of which many had prior programming experience, also outperformed the massed users.

A secondary focus of this research was the role that math background played on the performance of students in the course. The literature addressing this issue yielded contradictory results, ranging from having no impact to giving an edge. While no relationship was found with math background and achievement, student's ability to follow instructions, one of the skills tested for in the thinking skills measure, was a significant indicator of performance. Overall, the wide variability in use of the online learning environment demonstrated that this pedagogical model can effectively attend to differing needs of a heterogeneous student population. Encouraging students with low prior knowledge to make frequent use the online tools emerged as a recommendation for instructors and students alike

ACKNOWLEDGMENTS

I dedicate this work to my parents Aida and Eddie Acemian. If it were not for them immigrating to Canada, I would probably never have had the opportunity, as a female, to reach this level of education. My father believed in me throughout my educational journey and his words “Lâches pas” were always in the forefront of my mind, whenever I felt myself faltering.

I would like to thank my supervisor, Dr. Richard Schmid for his guidance and great patience during this lengthy voyage. I would also like to thank the members of my supervisory committee, Dr. Robert Bernard, for our many statistical discussions, which I will miss and Dr. Steven Shaw for his support the last few months of the voyage which were the most challenging.

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CHAPTER 1. INTRODUCTION

The purpose of this exploratory research is to determine the different uses by students of an online environment designed to supplement a face-to-face (F2F) university course and to assess the possible impacts on student performance. This section provides an overview of the reason for this research, how this research attempts to address the situation and concludes with the research questions.

What is the big picture?

Introductory university courses are mostly populated by first year undergraduate students with a large spectrum of knowledge: never having seen any of the content being presented all the way to students being familiar with some or most of the content. A newer reality regarding undergraduate university courses is that they contain a mix of traditional and non-traditional learners in a same class. The traditional undergraduate student is one who enrolls in university right after graduating from Cegep/high school and is typically between 18 and 24. The non-traditional student will have at least one of the following characteristics: delayed university enrolment, may be working full time while attending university, may have dependents (spouse, children, parents), is studying part time and did not complete Cegep (Oblinger & Oblinger, 2005). The non-traditional are working on a University degree, but may find it challenging to adhere to the set schedule. How do we as educators effectively deal with such a gamut of students in a same class? How do we as educators ensure that the ones who have some knowledge of the material being taught don't waste their time while those who are new to the content get the support they need to master the content? One way is to enable students to control their way of learning and what they review. Making students active participants in their learning is one way of keeping them engaged (Schank & Jona, 1991). Where we as educators can improve our students' learning and learning experience is to acknowledge their different needs at different times in their learning process. In an introductory course where the content covered is new to some students and familiar to others, the new student may need to go over the same content more than once; a more advance student will lose interest. "Control is a very important part of learning." (Schank et al., 1991, p.28).

The undergraduate students of today, which are mainly from the Net-Generation (born after 1990), cannot imagine living without technology or the Internet. They are referred to by Prensky (2001) as "digital natives", in other words "are native speakers of the digital language of computers, video games and the Internet" (p.1).

The traditional Net-Gener student expects to learn and socialize while at University. The non-traditional Net-Gener student wants to learn but may have difficulties complying with a rigid classroom schedule due to other responsibilities. As Prensky said (2001, p.1), "Our students have changed radically. Today's students are no longer the people our educational system was designed to teach." Our role as educators is no longer to be the sage on the stage as many of our Profs were, but to design courses to facilitate all students' learning, both the traditional and non-traditional Net-Geners. So our role as educators is changing from sages to facilitators (King, 1993).

Main focus of this study

To speak our "Digital Natives" (Prensky, 2001) students' language, it is natural for more of our educational materials to be available to students via the World Wide Web. At first, course websites were a repository for materials such as course syllabi, lecture notes, handouts and announcements. Consequently, students always had access to items they misplaced or handouts and messages they did not get as a result of not attending a particular class. With time, some teachers took online resources one step further by taking advantage of the interactivity of the Internet and its multimedia capabilities and realized that course websites could be much more than a mere repository of documents. Simulations and animations are just some of the new educational tools that are appearing on course websites. The next logical step was to offer courses strictly online with minimal or no F2F contact time. One would expect that the traditional students of today would be the first ones to want to learn online. Yet Oblinger's team (2005) reported that "traditional-age student say they come to college to work with faculty and other students, not to interact with them online. Older learners [non-traditional] tend to be less interested in the social aspects of learning; convenience and flexibility are much more important (p.8)." Educators were quick to realize that neither the conventional F2F, nor the fully online course were suitable for all students, all teachers and all courses (Franks, 2002). As a result mixed-method formats evolved, known as blended learning and web-enhanced models. F2F lectures are being complemented with online components. Such combinations maximize on the strengths of both the classroom and the online instruction. The F2F instruction allows for the human contact while the online instruction offers the flexibility of time and location (Driscoll & Carliner, 2005). Technology now offers a variety of design options when developing a course: a F2F lecture format with little or no use of online components (conventional format); a F2F lecture format with regular use of online components (web-enhanced); a blended format where students attend some F2F lectures, view others online, and make use of online learning objects (blended/hybrid learning) to enhance the in-class experience; a predominantly online format where students do most of their learning asynchronously online (e-learning). Wouldn't it be ideal if a course could be structured to entertain all of these formats at the same time? That is the course design proposed in this study (Acemian, 2012).

The primary purpose of this study is to identify and describe the factors that influence the effectiveness of a course design which offers students in an undergraduate-level course different blends of online and F2F so as to best meet their learning needs at different points in a course as opposed to having a single pre-set delivery mode for the entire term. The content and the assessment dates are pre-set by the educator and the students manage their learning format. By allowing students some control in the learning process we may improve the learning experience of more students as well as the actual learning. This is the goal of the course design used in this research. The idea is to allow the more novice student to go over content as many times as necessary while not imposing the same regiment on more advanced students. How do students make use of such an environment? Do the different formats impact their learning differently? These are some of the concerns being addressed in this study.

A secondary interest is the link if any of the mathematics background of students enrolled in a computer programming course. There is much discussion among computer science educators as to what are some of the best predictors of students' success in introductory computer programming courses. As the logic required to solve programming problems is similar to the one needed to solve mathematical problems, some argue that a student who has been exposed to math in high school and/or Cegep will have an advantage in an introductory programming course over someone who doesn't. The rationale is that to write a computer program you first need to design an algorithm describing the steps required to solve the problem at hand, which is similar to solving a math problem. Writing the algorithm is the most challenging part of programming. Following are the specific questions this research will be addressing.

Research Questions

This study is an exploratory one looking for interactions and does not attempting to test null hypothesis questions formed *a priori*, but allows the data to determine the hypotheses. There are two areas of interest.

Blended Learning and Web Based Learning Objects

1. Do students who use multimedia learning tools designed for specific cognitive skills via the course web page to complement a F2F class perform better than those who don't?

a) Is there a relationship between the use of "information tools" (annotated slides with audio, annotated slides with audio and video) to review the modeling of algorithm development and student performance?

b) Is there a relationship between the use of "cognitive tools" (interactive Java applets) to visualize the execution of code segments and student performance?

c) Is there a relationship between the use of "elaboration tools" (online quiz and paper-pencil exercises) for self-assessment and student performance?

2. How and why are students using the multimedia tools?

    a) What are the students using the tools for? To revisit concepts which are not mastered yet? To prepare for an exam? To prepare for an upcoming class?

    b) For those who don't use the multimedia tools, why are they not using the tools?

    c) Is there a difference in performance between student who use the learning tools on a regular basis compared to those who use them just before tests and exams?

3. Is there a difference in performance between students who follow the recommended personalized study guides and those who don't?

4. Which category of web based learning tools, "information, cognitive or elaboration", do students prefer to use?

5. Which category of web based learning tools, “information, cognitive or elaboration”, do students feel are more useful?

Prior Knowledge Transfer

6. Problem solving skills:
   a) Is the level of problem solving skills, regardless of prior mathematics background a good predictor of performance in an introductory computer programming course (CS1) course?
7. Mathematics background:
   a) Do students with different levels of prior exposure to Mathematics perform better in an introductory object oriented programming course than those with limited exposure?
      i. Does students’ prior exposure to specific Mathematics courses have an impact on performance in an introductory object oriented programming course (Bergin & Reilly, 2005; Wilson & Schrock, 2001)?
      ii. Are specific concepts acquired in Mathematics courses transferable to in an introductory object oriented programming courses?
   b) Does prior mathematics background juxtaposed with expected performance have an impact on performance in an introductory object oriented programming course (Rountree, Rountree, Robins & Hannah, 2004)?

Summary

The use of digital technology in education today is the rule and no longer the exception. Some digital tools are designed to replace the in-class experience while others complement it. What if we let the students decide how and when to use these digital tools during the term instead of imposing a usage pattern? What if we give them some suggestions of how to use these tools? What are the different usage study patterns employed by students?

The “raison d’être” of this study is to better understand how student are using the different multimedia tools available to them in an introductory university computer programming course and to offer some course design suggestions based on the findings of the usage patterns of these tools and students’ performance.

The next section looks at research on the various learning/teaching modes on the F2F and online continuum, self-managed learning, and describes the research framework used for this study.

CHAPTER 2. LITERATURE REVIEW

The objective of this research study is to identify and describe the factors that influence the effectiveness of an introductory F2F object-oriented programming course in which the technology provides additional instructional activities online. The students have the luxury of being able to switch between being a F2F student, an online student or a blend of both (blended/ hybrid learner) at will throughout the term. “While students recognise the value in the blend of face to face and technology supported activities, there are large individual differences in how they experience the blend” (Sharpe, Benfield, Roberts & Francis, 2006, p. 4). Oliver and Trigwell (2005) found that one of the weaknesses of the research on blended learning is that “what it is that teachers intend their students to learn (e.g. through blended/hybrid learning) may bear little relation to what it is that students actually experience” and that we need to look at the use of blended learning from the learner’s viewpoint (p. 22). Another point argued by Sharpe and her team is that “it seems to be important that students understand the role of technology in their learning and the implications for their study strategies and engagements in learning activities” (Sharper, et al., 2006, p. 4). In this vein the goal of this thesis is two-fold. On the one hand it is to analyse in depth students’ online use of learning objects by observing students’ navigation patterns when they are using the online learning tools in order to better understand the link between the learning process they are engaging in and its suspected effect on achievement to develop guidelines for students on the type of study patterns that seem to result in advancing their learning. On the other hand, based on the findings of the analysis, another goal is to make recommendations to course designers on the blends of F2F and online components that seem to ameliorate student learning.

F2F, Blended, Hybrid and Online Learning: What is the Difference?

What is meant by a blended, hybrid or online learner? Though what is meant by F2F and online courses (or learning) is clearer, there are a variety of definitions of web-enhanced, technology-enhanced, web-supplemented, blended, and hybrid learning. The term blended learning first appeared in the educational literature in 2000 according to Bliuc, Goodyear and Ellis, who in 2007 published a review on blended learning research. In some cases blended and hybrid learning are used interchangeably (Allen, Seaman & Garrett, 2007; Dzibuan, 2005; Graham, 2006) just as web-enhanced learning and e-learning are (Kirschner & Pass, 2001; Georgouli, Skalkidis, et al., 2008; Hermans, Haytko, et al., 2009). One definite distinction between blended and hybrid learning is that blended is used to refer to human learning exclusively whereas the term hybrid learning is found in human learning literature as well as in artificial intelligence literature to describe models for computer "learning".

In the educational literature, the term blended learning has been defined in many ways (Clark, 2003). Ross and Gage (2006) make a distinction between blended and hybrid learning. "Blended learning encompasses a spectrum of learning modes that range from the traditional face-to-face classroom to fully online degree programs" while hybrid means that part of the F2F time is replaced with "online learning activities" (p.156)". Hofmann (2002) sees blended learning as breaking up course content into chunks and then deciding on the best teaching strategies to deliver the material. These strategies could make use of classroom or lab settings, CD-ROMS, and asynchronous or synchronous or even stand-alone Web-based options to name a few. Graham (2006, p. 4) reported in his chapter in *The Handbook of Blended Learning* that for some, blended/hybrid learning is the use of different delivery media, for others the combination of different instructional methods and for others still a mix of F2F and online instructions. Vaughn's (2007) view of blended learning is its emphasis on active learning while reducing the classroom time. And many more variations can be found. Even though blended learning is a relatively new term and seems to be the rage of late, as Clark (2003) asked, is it "something old or new." One point that most agree upon regarding blended learning is that it makes use of technology. So if we go back in history, writing was one of the first technological waves that affected learning. Classes no longer needed to be just oral. Writing could be used and even better, once the printing press came to be, a new blend was added to learning: the book. The latest technological advance to impact learning is the Internet. So perhaps blended learning is just a new term for existing teaching strategies (Clark, 2003).

This lack of consensus on a definition for blended learning (hybrid learning) is seen by some as beneficial. Driscoll feels that "the point [that] blended learning means different things to different people [...] may appear to be an academic point but in reality these definitions illustrate the untapped potential of blended learning" (2002, p.1). "The lack of definition allows an institution to adapt and use the term as they see fit, and to develop ownership of it" (Sharpe, et al., 2006, p.19). And this is exactly what is happening in this study. Following are the possible teaching/learning classifications proposed in this study, which are a result of both the expected use of the Learning and Teaching Environment (LTE) by students when the researcher designed the environment and the observed way in which the learners used the LTE system (which will be described in detail shortly).

The Five Possible Teaching/Learning Classifications in This Study

Within the context of this study as a result of the course design (which will be elaborated upon in the next section), there is the possibility of five teaching/learning classifications ranging from F2F to online learning.

For the purpose of this study, web-enhanced, or web-facilitated learning is a F2F course which offers students online components which they use to enhance the in-class learning. These can include recorded/video streamed lectures, online interactive tools such as simulations and practice quizzes just to name a few. The main difference between web-enhanced and blended learning is that for the latter students decide to view lecture content online instead of experiencing them live in class. The F2F component allows for the human contact while the online component offers the flexibility of time and location (Driscoll et al., 2005) thus maximizing on the strengths of both the classroom and the online instruction. Most blended/hybrid courses available today 'impose' a blend on the learner. For example, Alonso (2011) proposed a course structure whereby students meet weekly in a F2F setting with the instructor to ask questions on the content they learned the previous week online. So students are exposed to new content online and meet the following week to do exercises in class with the instructor. A second course structure is one where all concepts are introduced in a F2F lecture, complemented by supervised F2F tutorial sessions which are then followed by students working online to complete activities and quizzes (Hatzipanagos et al, 2003; Wang, Fong & Choy, 2007). This format better fits the proposed definition of web-enhanced or as it is called in this study F2F-Hybrid as all lectures are F2F. The one commonality between these two course-structures just described is that the format of the blend is pre-set by the instructor and held constant during the term.

To recapitulate, the name and definition of the five possible types of learners in this study are:

- **F2F learner:** This student relies solely on the content delivered F2F by the instructor in class to learn. This learner does not use any online resources and can be categorized as a passive learner.
- **F2F-Repository (F2F-Rep) learner:** This is a F2F learner who also uses the documents in a repository posted on a course management system (CMS). These documents could include a course syllabus, assignments, and slides used by the instructor in class. Just like the F2F learner, the F2F-Rep can also be categorized as a passive learner, as the repository content has no interactive features.
- **F2F-Hybrid learner:** This is a F2F-Rep student who also makes use of the learning objects (LOs) available online in the LTE such as recorded/video-streamed lectures, simulations and formative quizzes. A F2F-Hybrid student

uses these LOs to supplement the in-class learning and not to replace any part of it. Some call this web-supplemented or technology-enhanced learning (Ross et al., 2006). The F2F-Hybrid learner is actively involved with the material on the LTE by interacting with simulations and completing online formative quizzes.

- **Blended learner:** This is a F2F-Hybrid learner who replaces some of the F2F lectures with both repository content and learning objects from the LTE.
- **E-learner:** This student relies on the CMS and the online LOs on the LTE for most of his/her learning as a substitute for most of the F2F lectures.

The five types of learners have the opportunity to manage their learning. They have the power to decide which tools to use and to some extend when, in the hope that they will better their learning. They can be passive learners by attending classes and downloading documents from the document repository (F2F and F2F-Rep learner) or active learners by interacting with the LOs from the LTE. They can oscillate between the different types of learners at will to meet their changing learning needs throughout the term.

Self-Managed Learning

We can look at learning as Ottewill does (2002) using the analogy of an iceberg (Figure 1). The portion of the iceberg that is above the water is "the time where the learning is directly facilitated by face-to-face contact between a member of academic staff and students" (p. 13), in other words class time. The portion below the water which is the larger chunk is the responsibility of the student. This is the portion that is self-managed. Just to clarify, self-managed differs from self-directed or self-regulated learning in that in self-managed learning the instructor "retains control of the learning outcomes, subject content and means of assessment" (Ottewill, 2002, p. 13). However in the literature, self-directed is at times used interchangeably with self-managed. It is the student's responsibility to make sure that the learning outcomes are achieved by a set time. This allows for a student centered design meaning "that students take more responsibility for their own learning within a framework that takes full account of their needs and aspirations and that a significant proportion of their learning time is essentially self-managed" (Jennings & Ottewill, 1996, p. 14). This accent on personal choice and control, important elements of learner autonomy, is important for distance learners (Doherty, 1998), just as it is for blended learners. Zimmerman (2002) pointed out that self-regulation is also important because it addresses a major educational goal, i.e., it enables the development of lifelong learning skills, a focus of most educational institutions today. This applies to self-managed learning as well. The introduction of different models of online education, ranging from blended to fully online, has provided a context well suited to encourage students to take control of their own learning. We need to remember that many of today's undergraduate students are working part-time or even in some cases full-time, and that time allocated to learning is time away from possible earnings, family and even socializing.

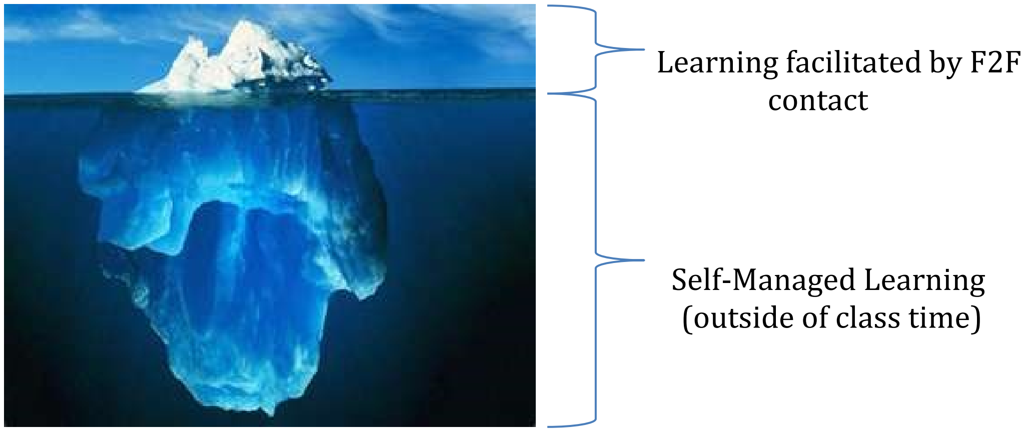

Figure 1. The iceberg of learning. [1]

The recent advances in computer technology have empowered educators to develop multimedia learning tools which allow students to continue their learning outside of class or instead of attending class, as well as to address the specific cognitive needs (Jonassen, 1999) of our "digital native" students. For example, animation tools can be developed to help students visualize the steps needed to solve a problem. A student can see an expert (instructor) model the process in class and then practise with an animation on their own time. Vygotksy argued (Gauvin & Cole, 2004) that expert scaffolding allows a novice to eventually achieve a goal or complete a task that s/he might not have been able to accomplish on their own. The instructor models in class the steps required to solve a problem, then students can practise with an animation and finally evaluate their learning with an online exercise which gives immediate feedback. F2F lectures, where the instructor introduces new concepts and models their use, can now be videoed and posted on course websites allowing students to re-view a lecture or parts of a lecture whenever and in whatever order they decide. These are options that were not as

[1] http://www.explorationinternational.com/LDBook.html; last visit June 5, 2013

readily available to students prior to the current advances in technology (Mayer, 1997). Again, technology facilitates the creation of such tools and the embedding of them into a web based environment allowing students to take control and responsibility for their learning.

Given these new types of learning tools and the freedom to use them or not, how do students integrate them into their learning strategies? How do they decide which tools to use and when? Is there a difference in performance between the students who use the tools and those who don't? In a 2006 study which looked at research publications on computer-based learning environments, Clarebout & Elen (2008) reported only "six out of the 21 studies on tool use report[ed] learning effects" (p.404) which were related to the type of tools, the way students used them and specific student characteristics. This implies that the "positive effects of tools cannot be taken for granted" (p. 405). Merrill (1980) suggested that giving students control of their learning allowed them to learn how to learn while learning the content. However, when students are given the freedom to choose from a menu of learning tools, will they make adequate choices if they don't understand the purpose and the possible advantages of using a specific learning tool? In a Belgian university study Clarebout et al. (2008) developed an environment to test the use of studying tools with and without advice. There were 185 first-year educational science students who were assigned to three groups: the adaptive advice (AA) group which "received advice adapted to their ongoing activities" (p. 85), the non-adapted advice (FA) group which "received advice on a randomly selected tool" and a control group (NA) which received no advice while working on an ill-defined problem with no single solution. In the advice giving versions students received advice when they logged into the system, every seven minutes and when they submitted their solution. “Participants in the FA-condition received non adapted advice on a randomly selected tool, while the AA-condition received advice adapted to their ongoing activities (p. 85).” The researchers found that “while advice had no influence on the total amount of tool consultation, it did have an effect on the proportion of time devoted to specific tools” (p.91). The NA group spent most of their time on videos where people were expressing opinions on the problem at hand which did not help in solving the problem. The AA and FA participants “spread their attention more evenly across the different tools” (p.92). The quality rather than the quantity of the tool use seemed to have been affected by the advice. Ross and Rakow (1981) reported that “students with little prior knowledge of the content presented profited from a computer-controlled sequence more than from one that was learner controlled” (p.223). In a study by Carrier, Davidson, Williams and Kalweit (1986) of 37 sixth-grade students using a computer-based lesson, students had the option of using various self-assessment tools as they progressed through an online lesson. Students’ general abilities were assessed based on school records while prior knowledge was not considered. As the students navigated through the lesson, some would see an encouragement message telling them that more practice was better. Students with the motivational messages chose more instructional tools than those who did not get the messages. The messages were general and not personalized and designed to be motivational rather than strategic. Perhaps if at first students are guided in their choice of tools and see results, they will be motivated by their performance and learn about learning at the same time. The level of prior knowledge has been shown to have an impact on the adequate use of tool use. It is difficult for students who are new to a topic to make informed or correct choices (Kirschner, Sweller & Clark, 2006). Winne (1995) adds that novices face a double challenge when trying to self-manage their learning: they lack the domain knowledge as well as the strategic knowledge to build the domain knowledge.

When evaluating the impact of tool use on performance, we need to know which type of tools students are using and how they are using the tools. To gather such data, we need to watch individual students as they navigate through the course website to record exactly their navigation patterns. With these data we might be in a better position to explore the relationship between patterns of use and performance and to make informed recommendations to novice learners on how to better manage their learning. Next we will discuss the research design and framework used in this study.

Research Design

This research adheres to the guidelines of a case study. Benbasat, Goldstein and Mead (1987) list 11 characteristics of case studies. An explanation of how this study fits these characteristics follows:

"1. Phenomenon is examined in a natural setting (p. 371) ". This research is not conducted in a controlled lab, but in the researcher's classroom with the consent of her students.

“2. Data are collected by multiple means (p. 371).” The data collected for this study includes students’ performance on three summative evaluations, responses to two survey questionnaires and the content of usage logs of online repository content and learning objects in the LTE.

“3. One or few entities (person, group, or organization) are examined” (p. 371). Two sections of a same course, taught by the same instructor in two consecutive terms are analyzed. One of the units of analysis is a group of students enrolled in the same course. However both group and individual students’ data are analyzed. This characteristic is therefore marginally true for this study.

“4. The complexity of the unit is studied intensively” (p.371). Students’ changing usage patterns of the online learning objects in the LTE was instrumental in discovering the five learning/teaching strategies listed earlier on in this chapter.

“5. Case studies are more suitable for the exploration, classification and hypothesis development stages of the knowledge building process; the investigator should have a receptive attitude towards exploration” (p.371). This study does not directly involve hypothesis testing, but is rather exploratory in nature. So our goal is not to test hypotheses formed a priori, but rather is to allow the data to determine the hypotheses.

“6. No experimental controls or manipulation are involved” (p. 371). The researcher has no control on students’ study behaviour. Students decide how to prepare for the summative evaluations, which tools to use, when to use them, how often and in what order. This follows from point 5: the variables emerge from the data rather than being manipulated.

"7. The investigator may not specify the set of independent and dependent variables in advance" (p.371). In this study most of the dependent and independent variables were set at the onset of the study. Prior knowledge and demographic data are examples of independent variables, while performance on summative assessments, class attendance and usage logs of the LTE are examples of dependent variables. The usage logs allowed the researcher to fine tune some of the data extracted during the analysis stage. These logs recorded which tool were accessed by whom and when, allowed the counting of the number of times a tool was used, the time spent each time a tool was used (in minutes), the total time spent on each type of tool, just to name few.

"8. The results derived depend heavily on the integrative powers of the investigator" (p.371). As the investigator in this study is also the instructor and the content expert, it might be more feasible to interpret, evaluate and deploy the results so that it is meaningful and effective for her students. The findings can be used to make decisions about course design and to make recommendations to students about study behaviors in an effort to improve their learning.

"9. Changes in site selection and data collection methods could take place as the investigator develops new hypotheses" (p.371). This did not occur during the main study, but there were some adjustments made after the pilot study prior to the main study.

“10. Case research is useful in the study of "why" and "how" questions because these deal with operational links to be traced over time rather than with frequency or incidence” (p.371). As can be seen by the research questions in Chapter 1 of this document, many of the questions are looking at how students are using the tools as well as why they are or not using the tools.

“11. The focus is on contemporary events” (p. 371). The events are contemporary as they are based on study behaviors and performance of students in an introduction to programming course interacting with learning objects designed using digital technologies not available some 20 years ago, such as video-streaming and interactive online tool.

Based on Benbasat’s et al. (1987) 11 characteristics of a case study, the design of this study satisfies nine of the 11 and marginally satisfies 2 of them (characteristics 3 and 7)

Research Framework

This study’s main objective is to examine the different degrees of blended learning and the effectiveness of each blend. It was therefore critical to identify a theoretical framework for the classification of identified and emergent variables, and their interaction. Jenkins’s (1979) “Theorist’s tetrahedron” is a widely cited framework that serves this function (Dorsey, Campbell & Russell, 2009). More specifically, Rieber (1994) in his section on *Interpreting Results of Instructional Visual Research* (p. 139) in his book on instructional design of visual information for learning recommends consideration of the interdependence of the learner, the learning activities, the learning materials and the testing environments, the four vertices in Jenkins tetrahedron. Similarly Najjar (1998) states that “in any learning situation, four basic factors should be considered when evaluating learning…: the characteristics of (a) the materials, (b) the learner,(c) the learning task, and (d) the test of learning” (p.311). Ahmad (2006) and Schugar (2008) are two examples where Jenkins’s tetrahedron was used in a doctoral dissertation to discuss the learning in a Nursing course and an English class respectively. Similarly in 1999, another group of researchers used a modified version of Jenkins’s tetrahedron to analyse medical, physiotherapy and science students’ approaches to learning with a computer aided tutorial session (Evans, Dodds, Kemm, Weaver & McCarroll , 1999) . Jenkins’s tetrahedron was developed to evaluate learning, and was used to provide a background for this project. This section will give a general explanation of Jenkins’s framework.

Jenkins’s tetrahedron is a four vertices pyramid (see Figure 2). It offers a 3-dimensional classification of the variables in a study evaluating learning. It reminds us that as researchers, we need to consider all of the components illustrated in the tetrahedron even if we are only analyzing or manipulating some of them. The four vertices of the pyramid are called *Subjects*, *Orienting Task*, *Materials* and *Criterial Tasks*.

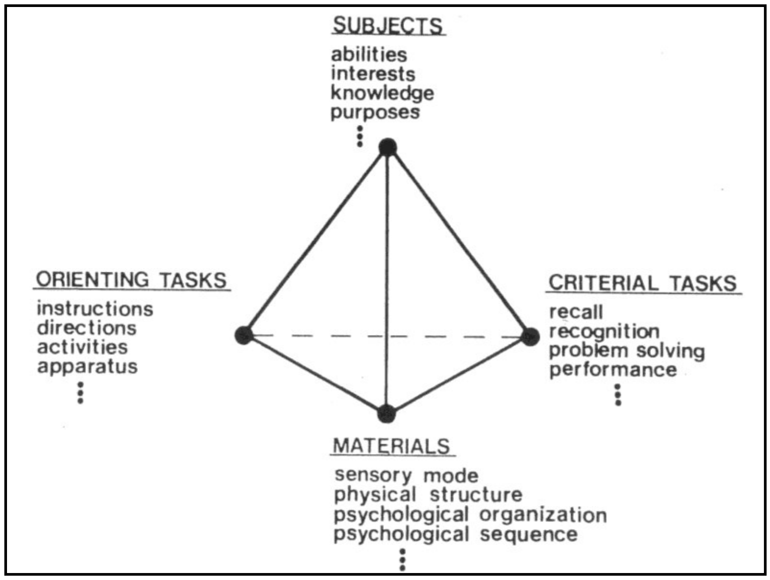

Figure 2. Jenkins's (1979) Theorist's Tetrahedron.

The *Subjects* vertex considers what the learners bring to the learning situation. This can include their maturity (age), gender, prior knowledge, expected performance on the task just to list a few possibilities. The *Criterial Tasks* vertex considers the goals (learning outcomes) of the instruction. They would list what the learner is expected to be able to do after the instruction session. A learning session can be one lab period, a workshop lasting anywhere from a few hours to a few days or even a complete course lasting a term or a year. The *Orienting Tasks* looks at the specific teaching/learning strategies used to master the expected learning outcomes. These can include the modeling of a process by an expert, giving the novice learner the opportunity to practice a newly acquired skill be it alone or in a group, guiding the learner through a series of embedded activities, allowing students the freedom to choose from a selection of non-embedded activities, or developing a concept map to show the relationship amongst different components of a course again just to name a few. The last vertex, *Materials,* looks at the actual implementation of the *Orienting Tasks*. It considers the means used to implement the *Orienting Tasks*. A web-based application which allows students to visualize a process, and the use of chats for working in a group are both examples of *Materials*.

The edges of the pyramid look at the impact of one vertex on the other. For example the *Materials-Criterial Tasks* edge can consider the impact of the frequency of use of the tool(s) on learning (mastering the criterial task(s)). The *Criterial Tasks-Orienting Tasks* edge can look at what Clarebout et al. (2006) call the "quality of the tool(s)" used, in other words whether the adequate instructional/learning method was used by individual students to learn. The *Orienting Tasks-Materials* edge can explain how, why and which learning/teaching strategy each tool (*Materials*) addresses. The base of the pyramid made up of *Criterial Tasks, Materials and Orienting Tasks* addresses the relationship of the three vertices. It helps frame such questions as how did the use of tool X (Materials) to learn task Y (Criterial Task) using modeling (Orienting Task) impact the learning. The last vertex *Subjects* considers the individual characteristics of the learner in the learning process and in the design of the tools. Perhaps gender has an impact on the criterial task (*Subjects-Criterial Tasks* edge) or maybe gender has an impact on the choice of tools an individual student will make which in turn impacts learning (*Subjects-Materials-Criterial Tasks* plane). Different tools may be developed for a same learning outcome with different student's characteristics in mind. Jenkins's tetrahedron helps the researcher consider all aspects of a learning situation even if he/she is exploring only a portion of the pyramid.

"Theorist's Tetrahedron" Applied to the Current Study. To best illustrate the validity of Jenkins's "Theorist's Tetrahedron" to the current study, the following section offers a description of each vertex in the context of this study, followed by an indication of where each research area is situated in the tetrahedron. In the vertices descriptions, even though not customary in a literature review section, to better juxtapose my course to the framework illustrated by Jenkins' Theorist's Tetrahedron, it was necessary to include details of the course in this section which would normally only appear in the Method section.

Criterial tasks vertex: The learning outcomes. Comp 218 Fundamentals of Object-Oriented Programming is a course offered by the Computer Science Department in the Faculty of Engineering and Computer Science at Concordia University. Looking at Bloom's Original Taxonomy (BOT), this course touches on five of six learning objectives of the taxonomy. Figure 3 lists the six levels of BOT[2]. In the following description of the criterial tasks, all verbs describing a learning objectives listed in BOT are italicized.

[2] http://epltt.coe.uga.edu/index.php?title=Bloom%27s_Taxonomy retrieved June 3, 2013

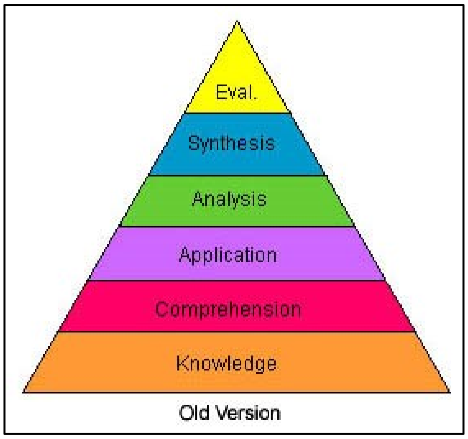

Figure 3. Bloom's original taxonomy.

The main learning outcomes as they appear in the course syllabus are:

- “Given a word problem understanding the problem specifications and formulating a solution (algorithm development)”:

  This requires a student to *analyze* a problem statement so as to *identify* the relevant information and *formulate* the finite steps required to solve it. The kernel of the skills required for this exercise is problem solving skills.
- “Acquiring programming knowledge which is of a declarative nature”:

  It involves being able to *describe* how a specific type of statement works for example how a “for” loop works and *describe* how to write one free of syntax errors (Robins, Rountree & Rountree, 2003). On Bloom’s taxonomy this requires *comprehension* and *knowledge*.
- “Acquiring programming strategies to generate programs”:

  This requires a student to identify the type of statement needed in a specific situation and how to *implement* it. For example a student will need to realize that a looping statement is required for a given problem, select the proper one and then write it with the correct syntax (Robins, et al., 2003). This requires the programming knowledge described in the preceding bullet as well as putting parts together to form a whole which in BOT fits under *synthesis*.

- "Program comprehension, understanding and describing what a program written by someone else does":
  This requires *analyzing* the program to *identify* the different type of statements, *comprehending* the purpose of each type of statement and *applying* this knowledge to *describe* how the different parts work together. This touches on the first 5 levels of BOT.

"At the end of Comp 218, students should be able to list the different types of statements, list the specific statements in each category, be able to write each statement syntax error free, describe what each category of statement is for and how each individual statement works, select the right statements to solve a problem and finally write a complete program to solve given word problems."

Orienting tasks and materials vertices: The classroom and online learning environments. The Orienting Tasks and Materials vertices will be described together as they are co-dependent. The course is a F2F class with a blended learning design. The course website serves as a repository for handouts and announcements as well as a learning environment that complements the F2F setting. Some terms the class meets twice a week during the day for 1 hour and 15 minutes and others once a week in the evening for 2.5 hours.

The lectures were enhanced by PowerPoint™ slides (Materials) which were developed by the instructor. The slides were available to students before class via the course website. The slides contain the main points that will be covered in class which include definitions and code segments that will be addressed during the lecture. The rationale of this approach is to allow students to fully benefit from the discussion in class and annotate their copy of the slides instead of spending their time copying what is projected and written by the instructor thus missing out on the ongoing discussion. This feeds the programming knowledge acquisition portion of the Criterial Tasks. The slides also contain examples which are discussed in class and exercises to be completed in class. Some examples are designed to illustrate the use of the different programming statements while others are there to allow the instructor to model the steps needed to understand programs written by someone else. The solutions to the exercises are not included in the slides. Instead of worked-out solutions, solutions are developed during the lecture. This allows students to witness the process an expert follows (modeling) to solve such problems along with the reasoning behind the actions. The aim here is to develop students' algorithm development skills and programming strategies. As there is more than one way of approaching a problem, students will record the solution they were involved in developing thus making the solution more meaningful to them.

The course website also has assignment handouts, solutions to assignments, tests and quizzes, a *WeekByWeek* page which highlights activities occurring each week (such as quizzes, exams and assignment due dates) and a list of topics that will be covered each week along with the slides that were needed for that week. Figure 4 shows a sample of the *WeekByWeek* page for the third week of class in the fall 2008 term.

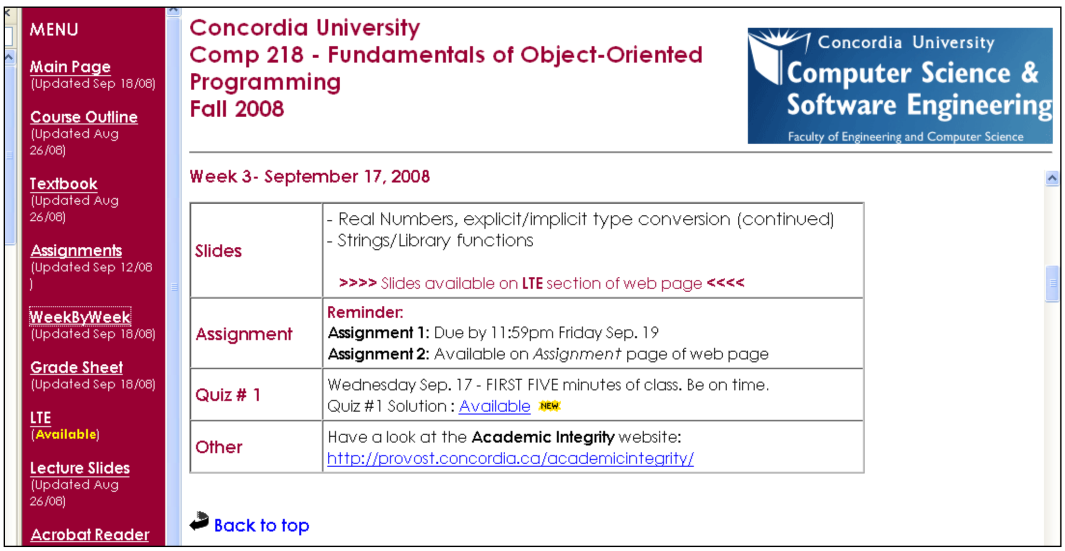

Figure 4. Sample of *WeekByWeek* page from Comp 218 course website.

Attached to the course web page is the Learning & Teaching Environment (LTE), which is the blended learning component of the course. This environment is a "non-embedded support" tool (Clarebout et al., 2006, p. 390) meaning that students are free to use or not use the tools available. Students are in control of their learning as far as their use of the tools in the LTE system is concerned. Each student decides which tools to use, how and when to use them and how often to use them. The purpose of the LTE system is to increase students' interaction with the course content and to reinforce their learning by enabling blending (Graham, 2006). It is also offering students additional resources without changing the teaching process.

The course content is broken down into main topics. The LTE system has a page for each main topic of the course which is then further subdivided into sub topics. There is a list of tools for each sub-topic with hyperlinks to activate the multimedia tools. Figure 5 shows a screen shot of the beginning of the *Repetition/Looping* topic page. The subtopics that are visible on the screen shot are *while* and *nested while* statements.

Figure 5. Screen shot of topic page for Repetition/Looping.

At the beginning of each term, students must subscribe to the LTE system to gain access to the web-based tools. Only students' registered for COMP218 are given access. The available tools are classified based on Clarebout et al. (2006) classifications which draw from Jonassen's (1999) categorization system for support devices. For details on the rationale for the choice of digital LOs included in the LTE, please refer to Appendix F. In this study three categories of tools were developed.

Information resources. The first, "information resources" offer students the background needed to construct their own view of the material and to then use this knowledge to solve programming problems (Clarebout et al., 2006). In CS1 courses, the dynamic aspect of algorithm development and analysis is a concept students find difficult to master. Bandura and McClelland (1977) suggested that individuals learn many skills through a process of modeling, in which behaviors are observed and imitated. The step-by-step construction and de-construction of algorithms is an important component of the teaching in CS1 courses (Lahtinen, Ala-Mukta & Järvinen, 2005). Applying Bandura's Modeling Theory, instructors model these processes while explicitly describing the rationale and the methodology required, in other words the how and the why. This in turn allows students to construct their own cognitive representation which will then help them perform the task at hand. Allowing students to revisit these explanations on demand outside of class time increases the chances of students building these cognitive representations.

During the COMP218 lectures the instructor used a PC tablet to annotate the slides as the lecture was being given. Using dynamic screen capture software called Camtasia™, everything written on the tablet was recorded, along with the voice of the instructor as the annotations were being made. In addition, the instructor was videotaped during the live lectures. These resulted in the creation of two weekly versions of the lectures; the F09 version which was two 1.5-hour recordings each week and the W10 which was one 3-hour recording each week. The videos were then cut up by topic and made available to students from the LTE system to view outside of class time:

- A Streaming (a RealMedia™) file of the lecture in which the instructor appears on one side of the screen, and the animated and annotated lecture slides were displayed simultaneously beside the "talking head". Refer to Figure 6 for a screenshot of the end result.
- A Macromedia Flash™ version of the narrated annotations to the lecture slides (no "talking head", just the animated and annotated lecture slides accompanied by audio). Refer to Figure 7 for a sample screenshot.

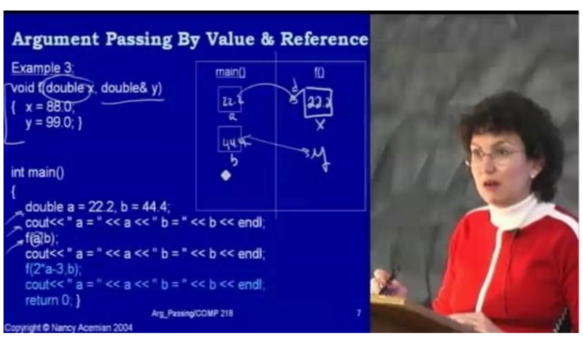

Figure 6. Streaming video format of lecture capture.

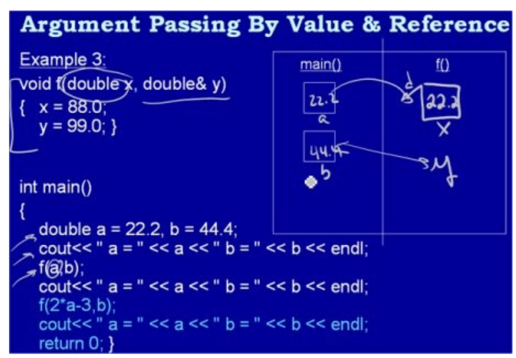

Figure 7. Flash format of lecture capture.

These were available for all topics/subtopics covered during the term. Students could revisit portions of lectures they did not understand when it suited them. In some cases even a missed class could be viewed thanks to these recordings. The teaching goal of capturing the lectures was to enable students to view and review the material at will exactly as it was presented by the instructor during the lecture.

The next two categories of tools, "cognitive and elaboration tools" (Clarebout et al., 2006), were developed for a limited number of topics. The decision on which topics to focus on was based on the instructor's/researcher's 20 years teaching experience of CS1 courses and published studies. Many studies asked instructors, students and teaching assistants what the most difficult concepts/topics were to teach/learn in introductory programming courses. The first two in the teaching sequence were conditional statements (selection) and repetition statements (loops) (Milne & Rowe, 2002; Lahtinen, et al, 2005; Kinnunen & Malmi, 2008). These are the topics for which cognitive and elaboration tools were developed.

Cognitive tools. The purpose of "cognitive tools" is to "help students to engage in and facilitate specific kind of cognitive processing" (Clarebout et al. 2006, p.393). The goal was to develop a program visualization tool, where the program segment is specified in the conventional, textual manner, and the graphics is used to visualize the execution of the segment via interactive simulations. The criterial task addressed here is program comprehension. Visualization is shown to be an effective way of improving static and dynamic aspects of objects oriented programming (Myers, 1986; Jerding & Stasko, 1994). The only way to include interactive visualization tools in an HTML page is with the use of Java applets. "An applet is a program written in the Java programming language that can be included in an HTML page, much in the same way an image is included in a page" (Sun Systems).

Care was taken to make sure that each learning tool focused on one and only one concept. As reported by Boyle (2003), borrowing from the principles of software engineering, when referring to the design of units that need to be maintained, re-used and repurposed, "each unit should do one thing and only one thing." Transferring this concept to learning objects, it was desirable to design tools that allow students to really understand each concept on its own first before combining them with other concepts (Lahtinen et al., 2005). Assignments were designed to combine the different concepts covered in class and were hence one of the tools used to give students the opportunity to synthesize their newly acquired knowledge.

One of the difficulties students experience in CS1 courses when tracing the execution of computer program segments, be it in their own programs or programs written by others, is the sequence of instructions being executed, the impact on variables and the output generated. There is a high cognitive load on the learner who needs to deal with these three aspects of code execution all at the same time. The applets were designed to help students see the content of variables change while following the flow of execution (Milne et al., 2002). The left hand-side of the applets contains the code segment being explored. To assist students, a scaffolding option was included which indicated the line of code currently being executed to help them follow the sequence. This was accomplished with the use of a coloured band which highlighted the statement in question. This feature was designed as a scaffolding tool. This option could be turned on or off at any time during the simulation. The on/off control was important to make sure students didn't become too dependent on this tool. The goal is for students to reduce the use of the scaffolding tool (the visual cue) and ultimately eliminate the cue as they master the concept simulated. Figure 8 and Figure 9 show screenshots of an applet running with the tracking tool turned on and off. A second feature was algorithm projection which served as a means to address the difficulties students have conceptualizing what happens in memory when a program is running (Kinnunen et al., 2008). In the box labelled Status panel the variables in the program segment are listed and their current content is updated as the statements in the code segment are executed. Refer to Figure 9 for a sample.

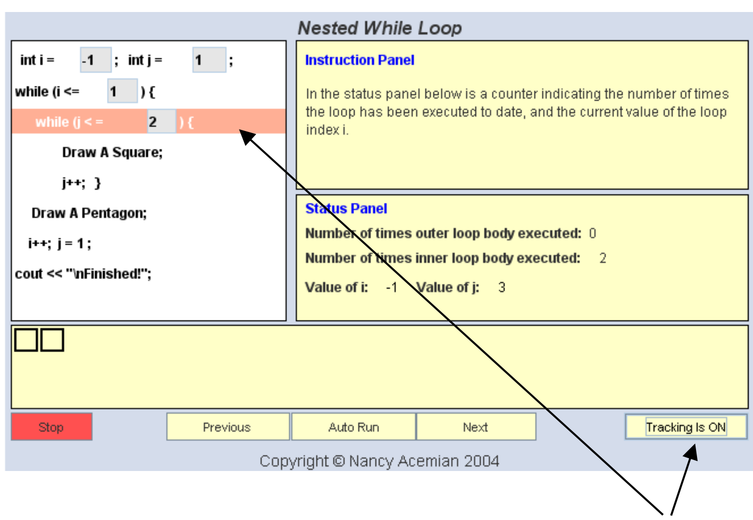

Figure 8. Screenshot of applet with tracking ON.

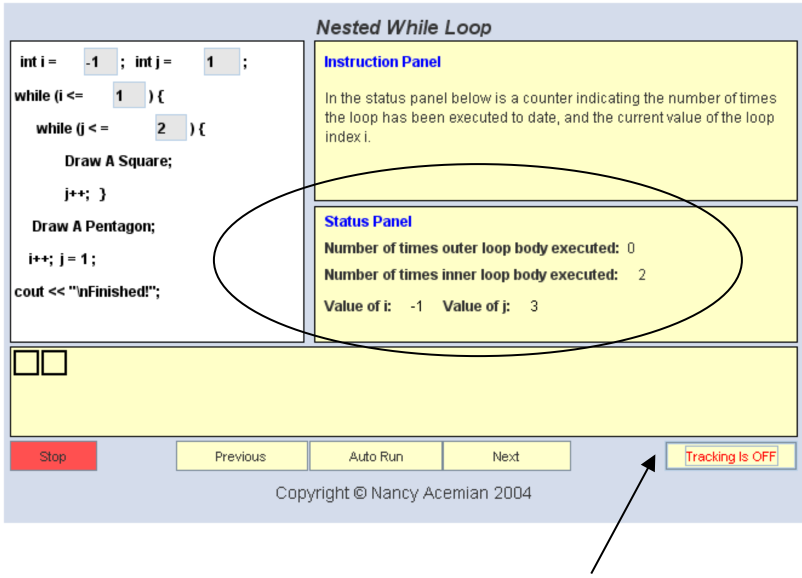

Figure 9. Screenshot of applet with tracking OFF (no scaffolding).

Another difficult concept in CS1 courses for students to grasp is nested control structures because of the extra load added on working memory. "Control structures nest much like mixing bowls do, with smaller ones tucked inside larger ones" (Dale, Weems & Headington, 2002, p. 224). Students have a difficult time describing the sequence of execution of programs which contain nested statements. To address this difficulty, a second scaffolding option was developed for some of the applets, a visual cue showing the level of nesting in a code segment in the form of coloured rectangles surrounding the different levels of statements. Figure 10 and Figure 11 illustrate this feature for nested selection statements. Just like the tracking feature, students could opt to have the nesting cue on or off and can activate and de-activate it at any time during the simulation.

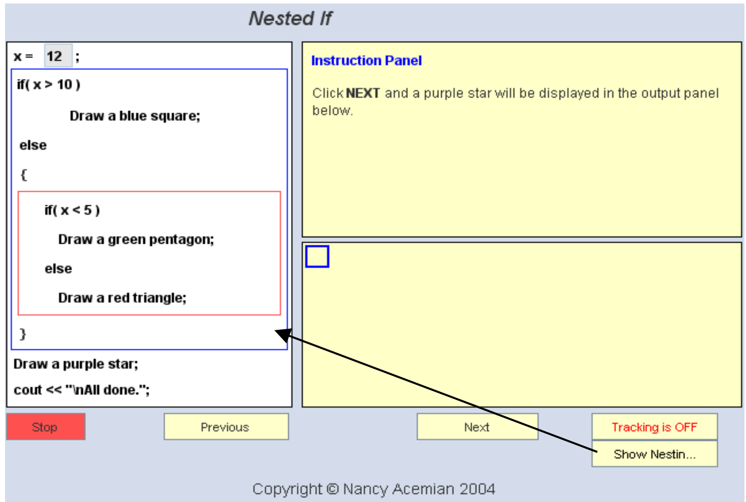

Figure 10. Screenshot of Nested IF applet with Nesting ON.

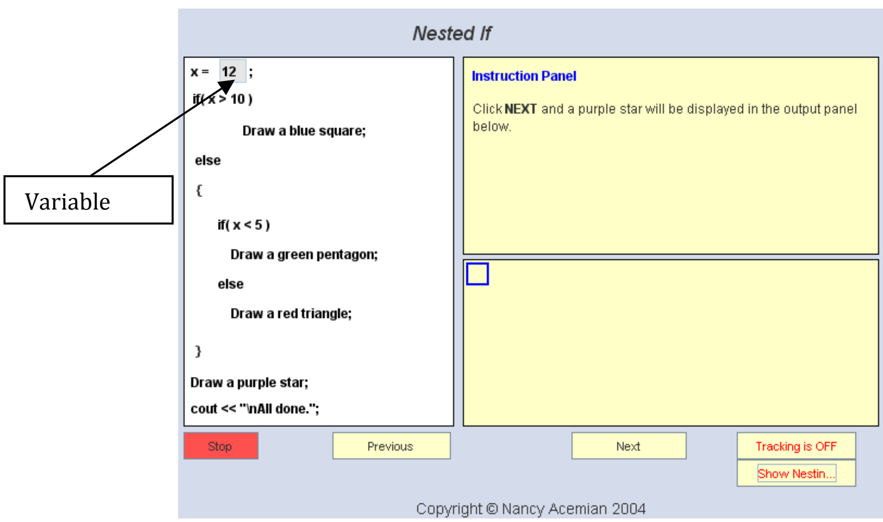

Figure 11. Screenshot of Nested IF applet with Nesting OFF.

At the start of the applets, students are required to enter variables in the grey variable box(es). The applet in Figure 11 has one variable box. Students could run the simulation with different sets of data which they enter in the grey boxes and decide on the level of scaffolding they require by clicking on the Tracking and **Show Nesting** buttons. Students are then instructed to predict what the next values for all concerned variables in memory will be, which statement will be executed next and the output that the execution of the next statement will produce if any. Every time they click on the Next button, the simulation executes the next statement in the sequence updating the relevant displays. Every time they click on the **Previous** button, the code backtracks one step, allowing students to see in reverse the step-by-step action that occurred. This tool allows students to 'play' with the code segments by trying different values and experimenting at their own pace. Since only one concept is addressed in a simulation, students develop their programming knowledge one concept at a time.

Elaboration Tools. The last category of tools included in the LTE system is "elaboration tools" designed so that students practice and evaluate their level of mastery of the concepts in the course (Clarebout et al., 2006). There were announced in-class quizzes which could be formative or summative (details in procedure section below) as well as assignments throughout the term. Also students' had access to online formative quizzes and a list of recommended exercises for each subtopic from the textbook with the solutions for self-assessment. The recommended exercises were for all topics while the online quizzes were for selection and repetition concepts only like the cognitive tools described above. The challenge in designing the online quizzes was to offer students a variety of questions without exercises repeating. The goal was to do this without creating a large bank of items. The solution was to have the values in the questions and the corresponding answers randomized and synchronized. The student were able to practise a same concept without seeing the exact questions repeated (Acemian, Woolsey, Devey

Zhang & Harzheim, 2008). They were developed using PHP, a widely-used general-purpose scripting language which is well suited for web development and which can be embedded into HTML pages. Question structures were kept constant while randomly generated constants were used in the questions and possible answers were synchronized to match the constants. The goal of these elaboration tools was again to offer students the opportunity to improve their programming knowledge and program comprehension capabilities. Figure 12 and Figure 13 show an example of a question taken from one of the online quizzes. It is the same questions with different constants. In Figure 12 the constants on the first two lines are 8 and 2, while in Figure 13 they are 5 and 3) and each have different answer options based on the randomly selected constants.

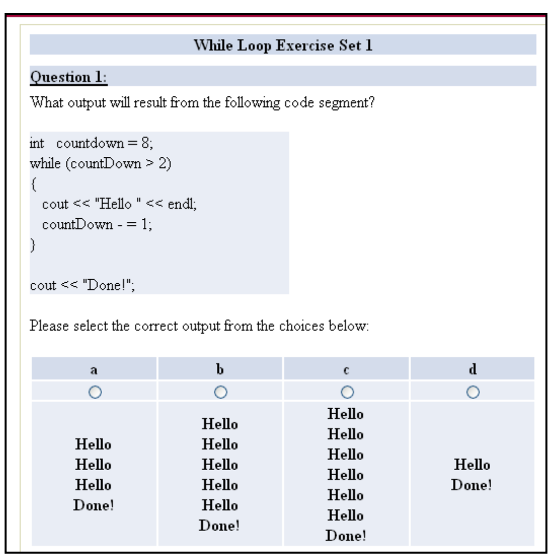

Figure 12. Sample question - version 1.

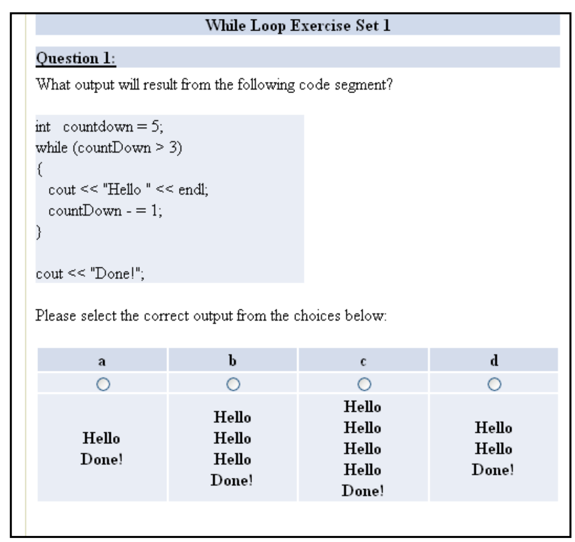

Figure 13. Sample question - version 2.

As a conclusion to this section, Table 1 below lists the learning tools described which are available to Comp 218 students' via the LTE system and their classification based on the categories described by Clarebout et al. (2006).

Table 1

List of learning tools, their availability and their classification based on categories used by Clarebout et al. (2006).

Learning Tools	Available where?	Information resources	Cognitive tools	Elaboration tools
Lecture slides for all topics– available online prior to class	LTE	X		
Annotated slides + narration by topic for all topics (LTE)	LTE	X		
Annotated slides + narration + video by topic for all topics(LTE)	LTE	X		
Live lectures F2F – all topics – IN CLASS	In class	X		
Simulation via Flash applets for selected topics (LTE)	LTE		X	
Announced optional in-class quizzes	In Class			X
In-class quiz questions and solutions	Course website			X
Online exercises on selected topics	LTE			X
Assignment handouts	Course website			X
Assignment solutions	Course website			X
Recommended exercises from textbook for all topics along with solutions (LTE)	LTE			X

Subjects vertex. The student population for this course is heterogeneous. Students are from different disciplines/programs with a variety of backgrounds hence different skills. However one characteristic that they all have in common is that they are not enrolled in a Computer Science programme, since COMP 218 is a service course dedicated to non-computer-science students. The academic backgrounds of students are also different. Some students are enrolled in a university program straight from CEGEP, some are mature students who have work experience and are returning to university on a part or full-time basis and some have already graduated from University recently and are back to complete another degree. Because of the large age range of our students at Concordia University, in a same class there are “digital native” as well as “digital immigrant” students (Prensky, 2001). This adds another level of diversity in students that an instructor needs to take into consideration when designing a lesson plan.

COMP 218 is typically populated by students enrolled in Mathematics, business and a mix of other programs.

COMP 218 is a required course for some students and an elective for others. Because of its high concentration of Mathematics majors it was felt it would be a good testing ground for the math vs. non-math advantage debate in CS1 courses. Most students enrolled in the class have limited to no programming background, which will be discussed next.

The Mathematics Background Debate. Introductory programming courses are seen as difficult by most university level students. One of the discussed factors in the success of non-computer (and computer science) students in introductory programming courses (CS1) is their mathematics background. This issue is a more specific example of Perkins & Salomon's (1989) question "are cognitive skills context-bound?" (p.16). There is much debate about the type of knowledge required for specific tasks. For example is general knowledge more valuable than specific knowledge of a field? As Perkins et al. (1989) report, some think that "good thinking depend[s] in considerable part on a repertoire of rather general heuristic knowledge" (p.17) and that the knowledge of a specific domain is not as important. Another line of thought is that "knowledge acquired in a particular domain is inherently general, at least implicitly, and should lead to transfer to other areas" (Perkins et al., 1989, p. 19). Perhaps problem-solving concepts learned in Mathematics could be transferred to programming problems. Many American studies report that the number of math courses taken in High School may be a predictor of students' performance in CS1 courses (Wilson et al., 2001; Evans & Simkin, 1989; Bergin et al., 2005; Rountree et al., 2004; Byrne & Lyons, 2001). As reported by Ventura (2005), Byron and Lyons found that the number of math courses taken seemed to be a more reliable predictor of success in CS1 courses than the score achieved on previously taken mathematic courses. Rountree and his team (2004) found that not only a student's math background was a good predictor of a student's performance in a CS1 course, but considering a student's expected grade as well was an even more reliable predictor of performance. At the other end of the math discussion spectrum, Ventura (2005) found that that there was no correlation between the number of math courses taken by a student or the math scores on standardized admissions test (SAT) used for admission to American colleges to performance in CS1 courses.

Considering some of the edges of the "Theorist's Tetrahedron." In this research the Materials and Criterial Tasks are constant, in other words they don't change from one offering of the course to another. However the students enrolled (*Subjects*) and how the students interact with the online tools is always changing. How the students interact with the LTE system is captured in the *Orienting Task/Materials* edge. How each type of student (*Subject*) be it students with a strong mathematics background or no-mathematics background, young or more mature students, full or part time students is captured with the *Subjects/Oriented* Tasks/*Materials* plane of the tetrahedron.

Before going on to the methodology of this research, Figure 14 offers a visual summary of the different components of this study in Jenkins's framework. The main components of each vertex are listed in a box adjacent to each vertex. The edges which are explicitly being analyzed in this study are tagged with an arrow pointing to a bubble with the question number(s) of the research question(s) being addressed.

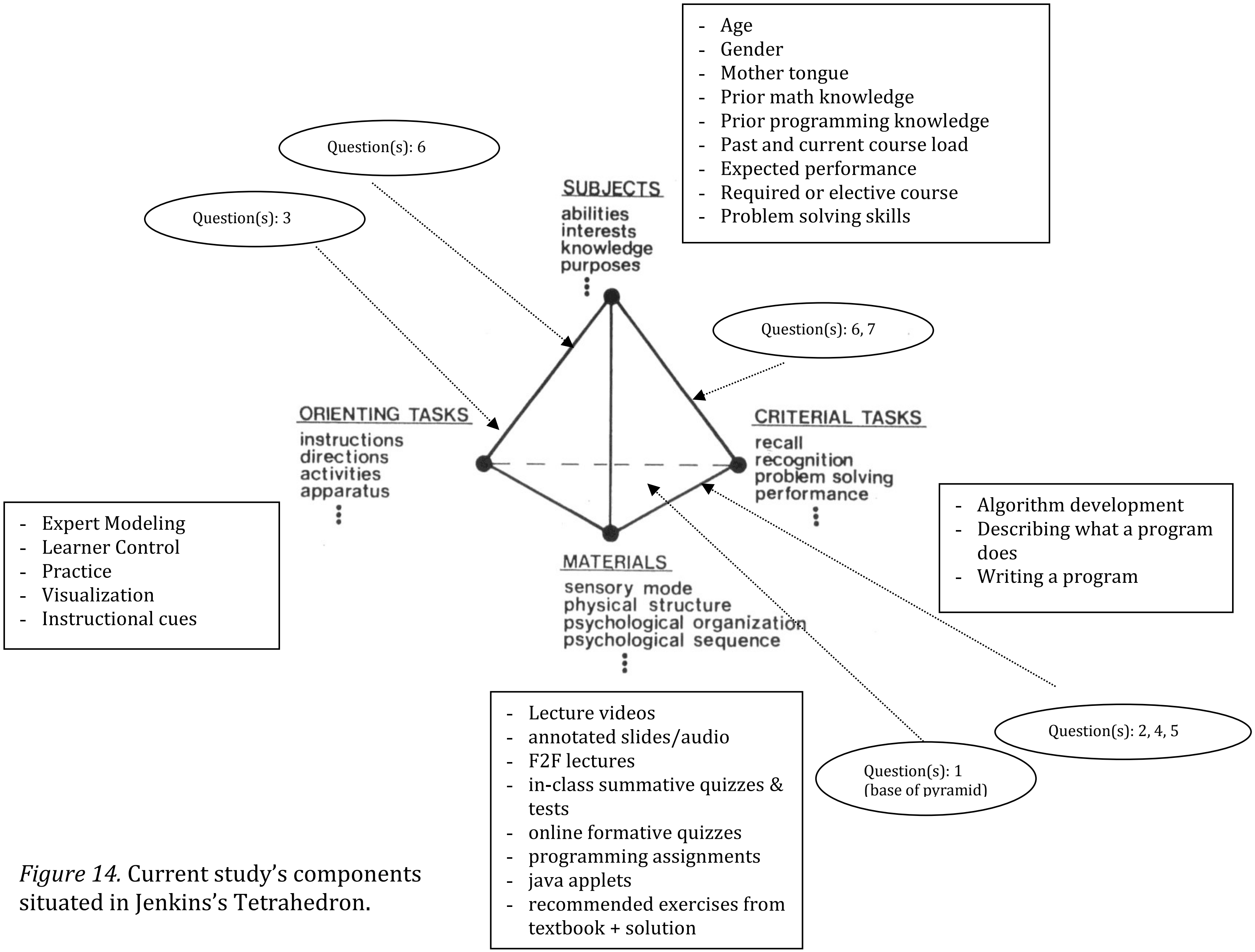

Figure 14. Current study's components situated in Jenkins's Tetrahedron.

CHAPTER 3. METHOD

The design of the main study is based on findings of a pilot study. This section will first describe the methodology for the pilot study along with some results, and conclude with the methodology for the main study, which is the focus of this thesis. It is worth noting here that the methods for the main study were very similar to the pilot.

Method for Pilot Study

This section describes the participants, the procedure, the data collection and instrumentation used and some results of the pilot study.

The pilot study was exploratory, as was the primary study. It lasted four years and data were collected from seven sections of the course described above offered by the researcher/instructor in that time span (Fall 2004, Winter 2005, Fall 2005, Fall 2006, Winter 2007, Fall 2007. The primary aim of the pilot study was to examine students' use of digital learning tools available via the course website juxtaposed with class attendance for the introductory object-oriented programming (OOP) course, Comp 218 Fundamentals of Object-Oriented Programming, at Concordia University. The students' use of these online LOs was captured in log files to identify the tools being accessed as well as when. The objective was to explore relationships across the use of the tools, class attendance and performance, as well as the relationship between program of study, namely mathematics, and performance.

Participants. The participants in the pilot study were undergraduate students enrolled in COMP 218. This course is offered by the Computer Science Department in the Faculty of Engineering and Computer Science at Concordia University. COMP 218 is a service course, meaning a course that is offered to non-computer science students and for which computer science students get no credit, should they take the course. The final N size was 236 out of a possible 302 student due to some students not filling out the consent form, a couple not giving consent, some not writing the final exam and finally some withdrawing from the course. Table 2 lists the exact numbers for each term.

Table 2

N sizes for pilot study from fall 2004 to F2007.

	F2007	W2007	F2006	F2006	F2005	W2005	F2004	Total
Original N	51	30	26	51	43	45	56	302
No consent form	3	0	2	3	0	0	0	8
Said No	1	0	0	1	0	0	0	2
Did not write final	5	5	5	5	2	5	2	29
Withdrew from course	6	0	0	6	6	9	0	27
Final N	36	25	19	36	35	31	54	236

Procedure. During the fall 2004 and winter 2005 the lectures were videotaped and the annotations made by the instructor on a PC tablet were recorded. From these recordings, Macromedia Flash™ files which included the annotations and voice-over were produced as well as corresponding RealMedia™ files which also included the videotaped portion of the lecture for video streaming.

At the beginning of the fall 2004 and winter 2005 terms, students were informed that the instructor would be videotaped during class (not them) and that the annotations done by the instructor during that time would be recorded using a PC tablet. All of these materials would then be available to them via the course web page. The instructor then proceeded to hand-out pre-generated personal user names and passwords to all students registered in the course to give them access to the Learning and Teaching Environment (LTE) where they would have access to the RealMedia™ and Macromedia Flash™ files. The best RealMedia™ and the Macromedia Flash™ files of fall 2004-2005 terms were incorporated into the LTE for the remaining four terms of the pilot study (Fall 2005, Fall 2006, Winter 2007, Fall 2007).

Ethics Approval. The pilot study is an extension of a research project the researcher embarked in while enrolled in a Research Methods and Designs course offered by two of the researcher's three thesis committee members (Drs. R. Schmid and R. Bernard). Ethical approval was granted at that time, involving the same design and participants.

Consent forms. For all sections of the course, the day of the first term test (week 6 of 13), the instructor addressed the class regarding the study. Students were informed that a new teaching method was being introduced and that their class was selected to help test it. Their support would be solicited throughout the term to give their opinions and comment on the new techniques by answering a few brief questionnaires. It was then explained that in order for their input to be used in the study, it was necessary that the instructor have their informed consent. The explanation included the following key points:

- Their final grades would not be affected in any way by their choice to participate and everyone in the class would have access to the same online tools.
- This research was confidential, but not anonymous. Their identity would be known only to the professor/researcher and research assistant (RA). The researcher would assign research identification codes to each participant for the purpose of the research to hide their identity making the research confidential. The researcher and/or RA would substitute each participant's user name with their assigned research identification code. The study was not anonymous in that each participant's activities would be tracked via their research identification code.
- When and if they logged onto the LTE website containing the LOs, their activities would be logged in order to monitor their use of the material.
- The only individuals who would be able to match a name to specific grades as well as to the use of the online teaching tools, were members of the research team. The identity of the students making use of these tools would never be revealed.
- No data provided by the student would be used if they opted out of the study.

- A contact person and her coordinates were made available to the students in order to allow them to withdraw from the study during the semester if they wished to do so.
- The results of the study would be made available to the students who requested it.

It was explained that the consent form was needed in order to make use of the information gathered via the log, the questionnaires, as well as to use their performance on the term tests and the final exam in the study. Once satisfied that the students were properly informed about the study, the instructor left the room while the consent form was distributed to the learners by someone who was not part of the research team (see Appendix A, Consent Form). The consent form used was adapted from the one used for the research project entitled "*An examination of learning environments using collaborative electronic concept mapping via synchronous and asynchronous computer-mediated communication"* (Schmid, McEwen, Locke & De Simone, 2002). The signed consent forms were placed in a sealed envelope, which was then given to the graduate program director's assistant in the computer science department to keep until the final course grades were submitted.

Students were also informed that they had the option of having the in-class announced quizzes count towards their final course grade or not. They had three choices:

- Choice 1 (Scheme 1 in course outline - Figure 15): Write the quizzes for summative purposes, in which case the average of the best six out of seven quizzes would account for 6% of their final course grad and each term test would account for 12%.
- Choice 2 (Scheme 2 in course outline - Figure 15): Write the quizzes for formative use, in which case they would be corrected and returned but would not count towards their final course grade. As a result, the term tests would each be worth 3% more (15% instead of 12%) to replace the 6% from choice 1.
- Choice 3 (Scheme 2 in course outline - Figure 15): Not write the quizzes at all, in which case just as in choice 2, their term tests would each count for 15% instead of 12% of their final course grade.

The course outline clearly indicated these choices as well. Students were asked to write the first quiz and to then decide which option they wanted before writing the second quiz. Each student was asked to complete a form indicating their choice and to date and sign it. Figure 15 summarizes the possible marking schemes as they appeared in the course outline.

Evaluation

The contribution of course components to the final grade for the course are shown below. There are two possible evaluation schemes. The differences are *italicized*.

Scheme 1 (Option 1)		Scheme 2 (Option 2 & 3)	
Assignments (5)	10% (5x2%)	Assignments (5)	10% (5x2%)
Term Tests (2)	*24% (2x12%)*	*Term Tests (2)*	*30% (2x15%)*
*Quizzes (up to 7)**	*6%*	*Quizzes (up to 7)***	*no credit*
Final Examination	60%	Final Examination	60%
* Please note there are no makeup quizzes.		**The same in-class quizzes will be available online for self-study after class.	

The 2 term tests are identical for either scheme – the difference is in the weighting (3% more per term tests in Scheme 2).

If you pick Scheme 2, you can still write the quizzes for practice, but they will not count toward your final course grade. All quizzes along with solutions will be posted on the course web page for all students in the course.

Figure 15. Possible marking schemes for COMP 218 as presented in the course outline for the pilot study.

Data Collection and Instrumentation. *The independent observed variables examined for analysis in the pilot study were:*

- Annotated slides + narration by topic for all topics
- Annotated slides + narration + video by topic for all topics
- Simulation via Flash applets for selected topics
- Online exercises with solutions for selected topics
- Recommended exercises from textbook for all topics along with solutions

There were four groups of dependent variables that were utilized during the course of the pilot study. The first group was to evaluate performance. This was done with the scores of the two term tests given during weeks six and eleven of a thirteen week term, the final exam which is administered during the official exams period after the end of the term and the six to seven quiz grades for those who wrote them which were spread out during the term approximately every other week, clustered between term tests. Care was taken to make all quizzes, term tests and final exams comparable across all sections of COMP 218 involved in the pilot study.

The purpose of the second group of dependent variables was to measure time spend on the online activities. The goal was to analyse the usage behaviour of the online resources to determine which of the LTE resources students' used, which topics they reviewed and the combination of resources they used. As each student navigated the LTE portion of the course website, their activities were recorded and stored in a text file. These data were instrumental in determining the time on task of each student. It also allowed the researcher to compare the popularity of the individual activities and examine the potential impact on performance. As soon as a student entered the LTE system with their personal username and password the log file was activated. Figure 16 shows an excerpt of the log file in a comma separated format (CSV). The following information was recorded:

- Log entry number (entry): each action in the LTE generated a new entry.
- Session id (sessionid): each time a student logged in to the LTE, the system generated a session id.
- The login name of the user (user): the content of this field was replaced by X in this document to respect the promise of confidentiality.

- Originating page (origin): the page they were currently viewing.
- The selected link (destination): the page they had requested.
- Time stamp (timestamp): which included the date and time the link was activated. The format of the time stamp is YYYYMMDDHHMMSS. This information would be used to determine the amount of time spend on each item/page as well as the overall time spent on the website.

```
cs218_history Table DATA DUMP
FIELDS : Entry,sessionid,user,origin,destination,timestamp

10484,90b154f84302c801046efb764437b384,X,Quiz Solutions,Assignment Page,20080110123015
10483,90b154f84302c801046efb764437b384,X,Lectures Slides,Quiz Solutions,20080110123015
10482,90b154f84302c801046efb764437b384,X,Quiz Solutions,Lectures Slides,20080110123012
10475,dfcba4c6d67ab8b8acfcefdd4abb3b23,X,Index,Index,20080110122022
14476,570db4d6c59f52f3fdb70f4266188830,X,Functions
Index,Flash_ArgPassing1YouTry1,20080322192536
14475,570db4d6c59f52f3fdb70f4266188830,X,Index,Functions Index,20080322192531
10481,90b154f84302c801046efb764437b384,X,Assignment Page,Quiz Solutions,20080110123009
10480,90b154f84302c801046efb764437b384,X,Index,Assignment Page,20080110123003
```

Figure 16. Sample of a log file in CSV format (Odd columns are highlighted for clarification purposes).

To help in the analysis, the log files were imported into Microsoft Excel™ (Figure 17) and then modified or as some call it pre-processed (Becker, Vanzin, Marquardt & Ruiz, 2006; Romero & Ventura, 2007). The modifications were essential to extract the necessary data for analysis. Data pre-processing involved the following steps:

- Data cleaning:

  Only consenting students' entries were kept for this research. All other entries including the instructor's and the tutors' were removed. To achieve this, the log entries were first sorted using the sort feature in Microsoft Excel™ by username and timestamp. The researcher scrolled through all of the entries in the sorted file and deleted the non-consenting students' entries as well as the tutors' and the instructor's.

- User identification:

  To fulfill the promise of anonymity of participants the user-names which students created the first time they logged in the LTE were replaced by research identification codes. The codes started with a letter to indicate the session (F for fall and W for winter), followed by the two last digits of the term year, a hyphen and a unique random number. For example F06_1 would be a student registered in the 2006 fall term and who would be identified as student 1 but who is not necessarily the first in the alphabetically sorted class list.

- Log entry timestamp:

  The *timestamp* field contains both the date and the time. To facilitate the calculation of time on task, this field was split into two fields, *Date* and *Time*. The elapsed time between two link selections was calculated to establish time on task (*TonTask*). This allowed the researchers to evaluate the number of sessions as well as the length of each session. As stated above a session starts when a student logs in to the LTE and ends when they log off. If a student does not navigate past the index page, it does not count as a session.

This is why just relying on the number of entries per student was not sufficient and the variable *TonTask* was necessary.

- Transaction type identification:

  To evaluate the effectiveness of the information resources, cognitive tools and the elaboration tools, each entry needed to be tagged. Video stream entries were coded with a V, flash voice over lectures with an **F**, online quizzes/exercises with an **E** and the simulation applets with an **S**. This allowed the tabulation of statistics on the number of times each of these resources was visited, and how much time was spent on them.

For example in Figure 17, we see that student F07_2 logged in at 3:30pm on December 17 (entry 9782/row 330 - is a login entry as the origin cell D330 is empty) and that the total time on task for this session was 3 hours 54 minutes and 42 seconds (cell Q354). We also see which pages and tools student F07_2 viewed and the time spend on each one of them during this session. Again looking at Figure 17 we see that user F07_2 viewed the lecture video on Arrays for 15 minutes and 42 seconds (cell P338). As we analysed the log entries it became apparent that students were spending a lot of time navigating the LTE and the TOT for each session were not indicative of the time spend actively interacting with the LOs. For example, row 353 shows that student F07_2 stayed on the Classes Topic page for 26 minutes and 23 seconds (cell P353) before going to the Classes Solution page. To be able to rightly evaluate the possible link between the choice of LOs and performance, it was necessary to distinguish between the navigation time and the time on the three types of LOs, namely information resources (recorded annotations and lectures), cognitive tools (simulations) and elaboration (to practise and evaluate mastery) tools

	A	C	D	E	F	G	H	N	O	P	Q
9	ORIGINAL DATA FROM LOG						CONVERTED DA				
10	Entry	user	origin	destination	timestamp		Date	Time	Activity	TonTask/ click	TonTask/ses sion
329	9618	F07_2	Index	Lectures Slides	20071217114028		20071217	11:40 AM		0:00:02	0:16:08
330	9782	F07_2		Index	20071217153057		20071217	3:30 PM			
331	9783	F07_2	Index	Index	20071217153057		20071217	3:30 PM		0:00:00	
332	9798	F07_2	Index	Lectures Slides	20071217155230		20071217	3:52 PM		0:21:33	
333	9982	F07_2	Lectures Slides	Index	20071217182543		20071217	6:25 PM		2:33:13	
334	9983	F07_2	Index	Lectures Slides	20071217182545		20071217	6:25 PM		0:00:02	
335	9984	F07_2	Lectures Slides	Index	20071217183031		20071217	6:30 PM		0:04:46	
336	9985	F07_2	Index	Arrays Index	20071217183036		20071217	6:30 PM		0:00:05	
337	9986	F07_2	~~Arrays Index~~	Video lec11 Arrays	20071217183037		20071217	6:30 PM		~~0:00:01~~	
338	10008	F07_2	Video lec11 Arrays	Arrays Index	20071217184619		20071217	6:46 PM	V	0:15:42	
339	10009	F07_2	~~Arrays Index~~	Index	20071217184624		20071217	6:46 PM		~~0:00:05~~	
340	10010	F07_2	Index	Arrays Index	20071217184628		20071217	6:46 PM		0:00:04	
341	10011	F07_2	Arrays Index	Index	20071217184631		20071217	6:46 PM		0:00:03	
342	10012	F07_2	Index	Classes Topic	20071217184634		20071217	6:46 PM		0:00:03	
343	10013	F07_2	Classes Topic	Video lec23-apr06 Cl	20071217184638		20071217	6:46 PM		0:00:04	
344	10028	F07_2	Video lec23-apr06 Clas	Classes Topic	20071217185344		20071217	6:53 PM	V	0:07:06	
345	10030	F07_2	Classes Topic	Flash_Class Impleme	20071217185347		20071217	6:53 PM		0:00:03	
346	10032	F07_2	Flash_Class Implemen	Classes Topic	20071217185415		20071217	6:54 PM	F	0:00:28	
347	10033	F07_2	Classes Topic	Video lec23-apr06 Cl	20071217185416		20071217	6:54 PM		0:00:01	
348	10037	F07_2	Video lec23-apr06 Clas	Classes Topic	20071217185745		20071217	6:57 PM	V	0:03:29	
349	10040	F07_2	Classes Topic	Flash_Class Impleme	20071217185901		20071217	6:59 PM		0:01:16	
350	10041	F07_2	Flash_Class Implemen	Classes Topic	20071217185904		20071217	6:59 PM	F	0:00:03	
351	10042	F07_2	Classes Topic	Flash_Class Impleme	20071217185906		20071217	6:59 PM		0:00:02	
352	10043	F07_2	~~Flash_Class Implemen~~	Classes Topic	20071217185909		20071217	6:59 PM	F	~~0:00:03~~	
353	10068	F07_2	Classes Topic	Class Solution	20071217192532		20071217	7:25 PM		0:26:23	
354	10069	F07_2	Class Solution	Classes Topic	20071217192539		20071217	7:25 PM		0:00:07	3:54:42

Fall2007LogWorkingCopy / ConsentCodes / TimeOnTaskAttendance / Scatterplots&F2F_Blend_DE / Fall2007Log

Ready

Figure 17. Sample of modified/pre-processed log file in Excel™ (Columns A to H and N to Q of rows 329 to 354).

A weekly running total of the time on task for each one of these activities as well as a cumulative running total of the three were therefore calculated. Figure 18, a different view of the same data as in Figure 17*Figure 17.* Sample of modified/pre-processed log file in ExcelTM (Columns A to H and N to Q of rows 329 to 354), reveals that student F07_2, in preparation for the final exam during week 16 of the term, logged a total of 3 hours and 54 minutes in the LTE but was making use of the LOs for only 41 minutes and 52 seconds of this time. The time a student interacts with the LOs is the data that will allow us to analyse the link between use of the LOs and performance.

E10 destination

	P	Q	R	S	T	U	V	W	X	Y	Z	AA
9	CONVERTED DATA											
10	TonTask/click	TonTask/session	Missing Data	Total # of clicks	Total # of Sessions	Total Time On Task		Date	RealTime on Task	Wk #	Real Time on Task per week	Total Real Time per block
329	0:00:02	0:16:08					3	20071217		16		
330							3	20071217		16		
331	0:00:00						3	20071217		16		
332	0:21:33						3	20071217		16		
333	2:33:13						3	20071217		16		
334	0:00:02						3	20071217		16		
335	0:04:46						3	20071217		16		
336	0:00:05						3	20071217		16		
337	0:00:01						3	20071217		16		
338	0:15:42						3	20071217	0:15:42	16		
339	0:00:05						3	20071217		16		
340	0:00:04						3	20071217		16		
341	0:00:03						3	20071217		16		
342	0:00:03						3	20071217		16		
343	0:00:04						3	20071217		16		
344	0:07:06						3	20071217	0:07:06	16		
345	0:00:03						3	20071217		16		
346	0:00:28						3	20071217	0:00:28	16		
347	0:00:01						3	20071217		16		
348	0:03:29						3	20071217	0:03:29	16		
349	0:01:16						3	20071217		16		
350	0:00:03						3	20071217	0:00:03	16		
351	0:00:02						3	20071217		16		
352	0:00:03						3	20071217	0:00:03	16		
353	0:26:23						3	20071217		16		
354	0:00:07	3:54:42					3	20071217		16	0:41:52	

Fall2007LogWorkingCopy / ConsentCodes / TimeOnTaskAttendance / Scatterplots&F2F Blend DE / Fall2007Log

Figure 18. Sample of modified log file Excel™ (Columns P to ZZ of rows 329 to 354).

The third type of data collected was class attendance to identify students who were still making use of the traditional lecture. At the beginning of each class, a sign-up sheet was passed around. This information allowed the researcher to subdivide the students into traditional and blended learners while gathering data about study habits. The criteria for this classification will be discussed in the pilot study's results section.

The final type of data collected was qualitative. This was desired to get a better sense of the perceived effectiveness of the online-materials. The data was gathered through two anonymous surveys given before each term tests. The timing was to ensure that the maximum number of students could fill out the survey. Since the term tests were in class, even students who relied on the online material would be present for the tests. The first survey contained mostly multiple choice questions (see Appendix B – Sample Student Survey #1). Its purpose was to gather data after 6 weeks of classes on what features of the website students used, how useful they found them, and why they used them. The second survey asked students to comment on their use of the different tools available on the course website (see Appendix C – Sample Student Survey #2). This survey was particularly designed to find out the reasons why a certain tool was used, or why it was not used, what students liked/disliked about the tools they used, and to gather any other comments they wanted to make. There is always the possibility that Survey #1 influenced some students who had not used the LTE up to that point to do so after. This is something that cannot be tested for and the only way to gather data on the use of the tools and comments.

The numerous dependent variables and the collection method are summarized in Table 3.. The main goal of the exploratory pilot study was to observe the relationship between the numerous variables to better prepare for the main study.

Table 3

Summary of dependent variables for pilot study.

Dependant Variables	Collection Method
Term Test 1	Term test 1 grade
Term Test 2	Term test 2 grade
Final Exam	Final exam grade
Quizzes	Quiz grades
Navigation patterns	Log file
Sessions total	Log file (calculated)
Total Time Online/Session	Log file (calculated)
Weekly and Total time on various online tools	Log file (calculated)
Attendance total	Sign-up sheet each class
Qualitative data	Anonymous Questionnaire
Program enrolled	Information in class list provided by the University

Some Results and Discussion. One of the concerns of the pilot study was to see if there was a difference in performance between traditional F2F students, mostly distance learners (DE) (those who did not come to class but used the online materials) and the blended student who came to all or some classes and made use of the online material. Four findings will be discussed.

Finding #1: *Types of learners – F2F, hybrid/blended and distance learners.* The researchers were surprised to discover that these three classifications did not occur. It was expected that since lectures were available online, as the term progressed some students would stop attending the F2F lecture and view the lectures online instead. Indeed, the option of evaluating the quizzes or not gave students complete freedom to not attend, without penalty. This did not happen. The students were in majority F2F learners (meaning they attended the majority of lectures). On average, of the 236 pilot study participants, 70% (165) of the students attended more than 70% of the lectures (at least 9 out of 13 weeks). Of these students some used the online resources and some did not. There were no 'true' DE students that emerged. Less than 10% (24) of the students attended less than 20% (three out of 13 weeks) of the lectures. Most students in this course are first and second year undergraduate students and are in the habit of attending classes throughout their primary and secondary years of schooling. They seem to have continued this pattern. Perhaps class time was considered as time well spent by students so even though content was available online, they decided to come to class anyway. Consequently the DE classification was dropped in the main study and students' were classified only by their use of the LTE.

Finding #2: Correlation between term tests and final exam scores. For the next part of the pilot study's results and discussion section, the findings for the 2007 winter and fall terms only will be discussed as they are representative of the results for the other five terms. The N size for winter and fall 2007 is 61. Table 4 lists the specifics of the N sizes for both terms.

Table 4

Fall and winter 2007 N sizes.

	F2007	W2007	Total
Original N	51	30	81
No consent form	3	0	3
Said No	1	0	1
Did not write final	5	5	10
Withdrew from course	6	0	6
Final N	36	25	61

The second finding I will discuss is the relationship between term test 1, term test 2 and the final exam scores. Term test 1 scores were a predictor for scores of term test 2 and the final exam. Term test 2 scores were a predictor of final exam scores as well. Table 5 and Table 6 show the correlations between test1, test2 and final exam scores for the last two terms (W2007 and F2007) of the pilot study. Note that the difference in N between term test 1 and 2 is due to some students missing term test 2 for medical reasons. The final exam for these students counted for 75% of the final course grade instead of 60% to make up for the missed exam. The relationship between test 2 and the final was foreseeable since test 2 is given in week 11 of a 13 week term. Most of the course content is covered by week 11, hence tested in term test 2. The second test is in fact a preparation for the final exam. It covers the topics which were discussed after term test 1 and they are the harder topics. This second test is a useful tool for students to identify the topics they need to review for the final exam. However, the degree of the relationship between term test 1 scores and performance on the final exam was unexpected Even though it is said that "the best predictor of future behavior is past behavior", one would expect students who performed poorly to take some corrective measures to be better prepared for the second term test and the final exam.

Table 5

Correlation coefficient of performance of students on term tests 1, 2 and the final exam for winter 2007 term.

	Term Test 2 Score	Final Exam Score
Term Test 1 Score	.716 ** (N = 22)	.776 ** (N = 25)
Term Test 2 Score	-----	.884 ** (N = 22)

(** significant at the 0.01 level)

Table 6

Correlation coefficient of performance of students on term tests 1, 2 and the final exam for fall 2007 term.

	Term Test 2 Score	Final Exam Score
Term Test 1 Score	.730 ** (N = 34)	.642 ** (N = 36)
Term Test2 Score		.752 ** (N = 34)

(** significant at the 0.01 level)

The implications of these findings for instructors, is that we need to reach out to students who are experiencing difficulties with the course content as soon as possible, and perhaps9 explicitly identify the concept(s) they are struggling with and offer them advise on how to improve. As stated in chapter 2, a novice student faces a double challenge: identifying what they don't understand and how to remedy the situation. The next step was to see what action students took after test 1 to better prepare for test 2.

Finding #3: Change in LTE usage pattern. One interesting finding regarding the use of the LTE, regardless of performance was the change in students' usage pattern of the LTE as the term progressed. As the term progressed, especially after the first term test, most students' use of the online tools increased. In W07, 68% (17 out of 25 students) and in F07 44% (16 out of 36) used the LTE more after test 1 than before test 1. This change in behaviour is one worth following. Perhaps students who would not normally use online resources began to do so as they became more comfortable with the online environment. Another possibility is that word of mouth may have contributed as well in promoting the features of the website. This increased use of the LOs in the LTE did not seem to impact performance on term test 2. There was no correlation between time spend on LTE and performance as was expected by the researcher. The researcher expected that students would look up the concepts they had difficulties with and make use of the LOs to perfect their understanding of the new material. A question that needs to be asked is who is using the LTE? Is it students who are having difficulties to begin with? Good students probably won't 'waste' their time on something they don't need. If they are performing well without the extra LOs why change their study strategies? Perhaps the weaker students are doing better with the use of the LOs than without but still not performing as well as the stronger students. As discussed in chapter 2, this may be a case of students having difficulties managing their learning. This may be an example of novice students not being able to make adequate decisions on which tools to use to better master the course content (Winne, 1995; Kirschner, et al., 2006). Maybe students are spending time on the wrong concepts. Maybe they are not clear on which concepts they don't understand. When giving students control of their learning they may have a preferred style of learning but that doesn't mean it is the best one for them. Perhaps explicitly telling students which concepts they seem to be having difficulties with and to recommend a study strategy to overcome these obstacles instead of letting them deduce it on their own would result . in a positive correlation between use of LTE and performance.

Finding #4: Relationship between mathematics background and performance. All seven groups in the pilot study were included in this analysis. The results were not consistent. There was a significant relationship between Mathematics background and performance on the final exam only for students in some day sections but not for evening sections. The correlation was significant for two out of the five day sections but was not consistent. In the fall 2006 day section the Mathematics students significantly outperformed the non-mathematics students while in the winter 2006 day section the non-mathematics students significantly outperformed the mathematics students. Table 7 shows the specific correlation coefficients and Table 8 the final exam means for each section.

Table 7

SPSS output for correlation between program of study (math or non-math) and term tests and final exam results.

			Test 1 Score	Test 2 Score	Final Exam
Winter 2007 Evening Section	Pearson Correlation	1	.102	.166	.196
	Sig. (2-tailed)	.	.628	.460	.347
	N	25	25	22	25
Fall 2007 Day Section	Pearson Correlation	1	.217	.133	.442(**)
	Sig. (2-tailed)	.	.204	.452	.007
	N	36	36	34	36
Fall 2006 Day section	Pearson Correlation	1	-.369	-.357	-.536(*)
	Sig. (2-tailed)	.	.159	.175	.032
	N	16	16	16	16
Fall 2006 Evening Section	Pearson Correlation	1	.017	.286	.158
	Sig. (2-tailed)	.	.939	.176	.460
	N	24	24	24	24
Winter 2005 Day Section	Pearson Correlation	1	-.086	-.164	.140
	Sig. (2-tailed)	.	.644	.377	.451
	N	31	31	31	31
Fall 2005 Day Section	Pearson Correlation	1	.026	-.104	-.097
	Sig. (2-tailed)	.	.879	.544	.574
	N	36	36	36	36
Fall 2004 Day Section	Pearson Correlation	1	.097	.220	.122
	Sig. (2-tailed)	.	.517	.138	.424
	N	47	47	47	45

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Table 8

SPSS output: Mean of Final exam scores for math and non-math students in all sections of COMP218 considered in the pilot study.

		N	Mean	Std. Deviation	Std. Error Mean
Winter 2007 (Evening)	Math	7	46.29	29.35	11.09
	Non-Math	18	55.31	17.29	4.08
Fall 2007 (Day)	Math	16	55.94	15.55	3.89
	Non-Math	20	71.23	16.08	3.60
Fall 2006 (Day)	Math	6	83.75	8.29	3.38
	Non-Math	10	65.15	17.88	5.65
Fall 2006 (Evening)	Math	11	63.95	17.36	5.23
	Non-Math	13	69.31	17.38	4.82
Winter 2005 (Day)	Math	10	39.39	16.26	5.14
	Non-Math	19	44.42	13.04	2.99
Fall 2005 (Day)	Math	9	71.94	17.433	5.81
	Non-Math	27	67.81	19.33	3.72
Fall 2004 (Day)	Math	20	67.90	21.17	4.73
	Non-Math	25	72.24	14.82	2.96

As discussed in Chapter 2, many have argued that math background has no impact on student performance in a CS1 course while others have argued that there is some relationship. . Based on over 20 years of teaching experience, the researcher/instructor would have sided with the opinion of the second group. As mentioned above, a math student for the pilot study was any student enrolled in a mathematics program at the University level (Mathematics and Statistics, Statistics, or Actuarial Mathematics).The rationale behind this was that the mathematics prerequisites for admission into a university level mathematics and computer science programmes are the same (Calculus I and II and Linear Algebra I) hence students would have the same mathematical background and more than the non-science students enrolled in the course. The results from the pilot study are inconclusive and support the inconsistent findings reported in the literature on this topic.

This concludes the findings of the pilot study. The next section will look at the methodology for the main study focusing on the modifications to the methodology and the rationale for these changes.

Method for Main Study

The method for the main study is based on the pilot study. Modifications to the method of the pilot study will be highlighted.

Ethics Approval. A summary protocol form (SPF) was submitted to Concordia University's Human Research Ethics Committee for the main study. It was approved prior to analysing the data. See Appendix D for the SPF.

Participants. The sampling is purposive/convenience, similar to the pilot study. Participants consisted of students from two sections of COMP218, FUNDAMENTALS OF PROGRAMMING, at Concordia University. The sampling is purposive as the LTE being studied was designed for this introductory computer programming courses. The limitation of this approach is that the findings will only be based on non-computer science students enrolled in an introductory programming course and may not be generalizable to computer science and software engineering students enrolled in a CS1 course. It is convenience sampling as both sections were taught by the researcher in two consecutive terms, fall 2009 (F09) and winter 2010 (W10). The F09 section was a day section; hence there were two 1-hour and 15 minutes meetings weekly. The W10 evening section met weekly for 2.5-hours. There is no control group at the onset of the study as it would be unethical as an educator to restrict access to some students to tools that could improve their learning experience hence their learning. As we will see in the results section, a control group did emerge; the membership to this group was not controlled by the researcher but occurred naturally when some students did not make use of the LOs in the LTE.

Summative Evaluation Schedule. The length of a term at Concordia University is 13 weeks. The total contact hours were the same for both terms. The schedule for quizzes and term tests was the same for both sections. The only difference was that in F09 there were seven in-class quizzes while in W10 there were six, and the final exam for F09 was held two weeks after the last day of classes while for W10 it was three weeks after the last day of classes. Table 9 shows the schedule for the formative evaluations for each section.

Table 9

Quiz, term test and final examination schedule for F09 and W10.

	F09	W10
Quiz 1	Week 3	Week 3
Quiz 2	Week 4	Week 4
Quiz 3	Week 5	Week 5
Term Test 1	Week 6	Week 6
Quiz 4	Week 8	Week 8
Quiz 5	Week 9	Week 9
Quiz 6	Week 10	Week 10
Term Test 2	Week 11	Week 11
Quiz 7	Week 13	- - - - - - - -
Final Examination	2 Weeks after last day of classes	3 Weeks after last day of classes

Procedure. The classroom and online environments for the main study were the same as for the pilot study. All students registered for COMP 218 were given access to the LTE system. Instead of generating and handing out unique logins to each student, the LTE was modified so that each student registered to the LTE and chose their own login name and password. The instructor imported the student IDs from the class list into the LTE database. The first time students accessed the LTE they were prompted to enter their student id and to create a login and password. Only students whose student identification code was in the database were allowed to register to the LTE.

Consent forms. For both terms consent forms were distributed on the day of the first term test following the same procedure as for the pilot study. The same consent form was used for both terms. A copy is included in Appendix A.

Formative evaluations marking scheme. The marking scheme for the course was modified for the main study. Students' no longer had the option of having or not having their quiz scores count towards the final course grade. This option was given to students in the pilot study since it was expected some students would be distance learners and attend a minimum number of classes. Forcing them to come to class for a quiz would take away this option. Since 70% of the students attended over 70% of the lectures in the pilot study, in the main study all students were required to write the quizzes and the scores counted towards their final course grade. Figure 19 shows the evaluation section of the course outline for the F09 and W10.

Evaluation

The contribution of course components to the final grade for the course are shown below.

Assignments (5)	10% (5x2%)
Term Tests (2)*	24% (2x12%)
Quizzes (up to 7)*	6% (Will consider best 6 out of 7 scores)
Final Examination	60%

* Please note there are no makeup term tests or quizzes.

Figure 19. Evaluation Section of course outlines for F09 and W10, sections of COMP218 considered in the main study.

Summative evaluations' feedback to students*.* For the main study feedback given to students after each quiz and term test was more elaborate. Quizzes contained one question and students had five minutes to answer it. Solutions were posted on the course web site (which is all that was given for the pilot study) along with a recommendation of how to review this topic. Relevant pages in the textbook, links to the specific information tool(s) to review and any other learning tools that were available in the LTE for the concept covered in the quiz were enumerated. The feedback for the term tests was now personalized. When returning the graded term tests, a feedback form was appended to each exam itemizing the concepts the student seemed to be having difficulties with along with a recommended study guide which focused on the use of the LOs from the LTE. This personalized feedback was to address the difficulties students in the pilot study seemed to be experiencing when trying to self-manage/regulate their learning (Kirschner et al, 2006: Winne, 1995). All students were given feedback regardless of their performance; for weaker students it was more elaborate while the stronger students were told to continue with whatever strategy they were using to date. A sample completed feedback sheet for term test 1 is included in Appendix E. Note the student's name has been covered to preserve the promise of confidentiality.

Data Collection and Instrumentation. Two questionnaires were distributed in both terms. Students were asked to include their names and student ID on both questionnaires unlike the pilot study where they were anonymous. This was to allow the researcher to link the questionnaire responses to the LTE usage log and performance of each student.

Questionnaire #1. The first questionnaires collected demographic data about the students, their math background and their problem solving skills. It was handed out in class in the 6th week for F09 and 4th week for W10. Students were given time during class to complete the survey. The following additions were made:

- To better understand a student's math background, students were asked details about the number and type of math courses they had taken to date and were taking concurrently to COMP218, instead of relying on their enrolled program as was done for the pilot study. The eight CEGEP math courses were listed and students were asked to indicate which they had taken in CEGEP. The courses were Calculus I, II and III, Linear Algebra I and II, Probability and Statistics, Finite Mathematics and Differential Equations. Students were also asked to report the number of university level math courses they had taken and were presently taking.
- To rate student's problem-solving skills notwithstanding their math background and enrolled program, a seven question quiz was administered. The questions were taken from the survey used by Evans et al. (1989) which is a subset of the one used by Mayer, Dyck and Vilberg (1986). Refer to questions 22 to 28 in Appendix B for the seven questions.
- To better understand their course load, students were asked if they were part-time or full time students, the average number of courses they had taken per term to date and the number of courses they were taking this term.

- To better understand their maturity, students were asked their age. This was done by giving age ranges for students to pick from: less than 24, 25 to 35, or over 35.
- To study the relationship between expected performance, the use of the multimedia tools (LOs) and actual performance, students were asked to check-off the grade they expected to earn in this course: in the As, in the Bs, in the Cs or less than C-.

A copy of the questionnaire is included in Appendix B.

Questionnaire #2. The second questionnaire asked students to report on their use of the LTE, just like in the pilot study, to gather qualitative data to better understand why students used the tools they did, why they didn't, what they used the tools for and any other comments they wished to add regarding the environment. New for the main study were questions on the use of the textbook. The objective was to find out if student had access to the textbook (did they buy one or use someone else's) and if so what they used the textbook for. Was it to review material covered in class, to catch up on missed material, to prepare for class, to look at other examples than those presented in class, and/or to do the exercises at the end of chapters? A copy of the questionnaire is included in Appendix C.

Attendance sign-up sheets. Sign-up sheets were passed at the start of each class, just like it was done during the pilot studies. This was to record attendance in the F2F lectures.

Log Files. There were no changes to the log files format for the main study.

Dependent and independent observed variables. Table 10 summarizes the study's variables and how they were gathered.

Table 10

List of independent variables for main study.

Independent Observed Variables	Collection Method
Age	1st questionnaire
Mother tongue	1st questionnaire
Math background	1st questionnaire
Enrolled program	Class list provided by the University & 1st questionnaire
Part-time or Full-time student	1st questionnaire
Course load	1st questionnaire
Expected performance in course	1st questionnaire
Problem Solving Skill	Pre-Test on 1st questionnaire
Qualitative Data on use of LTE	2nd questionnaire
Textbook use	2nd questionnaire
Navigation patterns	Log file
Total Time Online/Session	Log file (calculated)
Weekly and Total time on various online tools	Log file (calculated)
Attendance Total	Sign-up sheet each class

Even though only the term tests and final exam scores were used in this study to evaluate performance, records of students' performance on all assignments, quizzes, term tests and final exam were entered in an Excel spreadsheet which is standard procedure for all courses. As all term tests with individual feedback sheets are returned to students once they are graded, photocopies were kept to monitor the extent to which students followed the recommendations in the personalized study guides and to help evaluate the impact on subsequent exams. These were used to monitor the progress individual students were making on a continuum of the different concepts throughout the course. In the data analysis, these were juxtaposed with students' use of the LTE tools for each of the programing concepts as well as the individualized study guides appended to the two term tests.

Table 11 summarizes the dependent variables and how they were collected. For the main study, only the two term test and final examination grades were used to evaluate performance. The quizzes count for 6% of the final course grade therefore did not have a large impact on the final course grades. Assignment grades were also dropped for the analysis as assignments are not a true reflection of students' knowledge. Many students admitted to solving assignment questions by trial-and-error and that if asked to redo the assignment they would still have troubles. Some students had a 'lot of help' in completing the assignments from friends. Thus, assignment grades were not necessarily either valid or reliable measures of their learning, even though the process of completing them was assumed to be potentially instructionally useful.

Table 11

List of dependent variables for main study.

Dependant Variables	Collection Method
Term Test 1	Grade of Term Test 1
Term Test 2	Grade of Term Test 2
Final Exam	Grade of Final Exam
* Navigation patterns	Log file
* Total Time Online/Session	Log file (calculated)
Weekly and Total time on various online tools	Log file (calculated)
* Attendance Total	Sign-up sheet each class

The variables marked with an asterisk (*) in Table 11 are considered as both dependent and independent variables, as perhaps a student's performance on a term test has an impact on how they use the LTE in the following weeks and how often they attend class.

In the next section the findings of the main study will be discussed.

CHAPTER 4. RESULTS AND DISCUSSION

This section will report the results of the main study along with a discussion of the results.

Demographic, Attendance and Performance Data

There were 78 students who consented to participate in the study (47 in F09 and 32 in W10). In the F09 term two of the 47 students did not write the final exam. In the W10 term, four of the 32 students did not fill out the demographics questionnaire and one did not write the final exam, which means the actual sample size is 72 students (45 from F09 and 27 from W10).

Student demographics. One of the foci of this study was to look at the impact of the use or non-use of the different components of the LTE on students' performance as was done by Byrne et al. (2001), Evans et al.(1989) and Konvalina (1983) to name a few . The first step was to determine if students' characteristics alone such as gender, age, mother tongue, full/part-time status, programming and mathematics background and thinking skills had an impact on performance before looking at the LTE use to determine, as a course designer, if any interventions could be included at the onset of the course to address these characteristics specifically. Referring back to Jenkins' Tetrahedron, this section is looking at the Subjects' vertex, namely what the learner brings to the learning setting. Figure 20 lists the characteristics being considered within the context of Jenkins, tetrahedron.

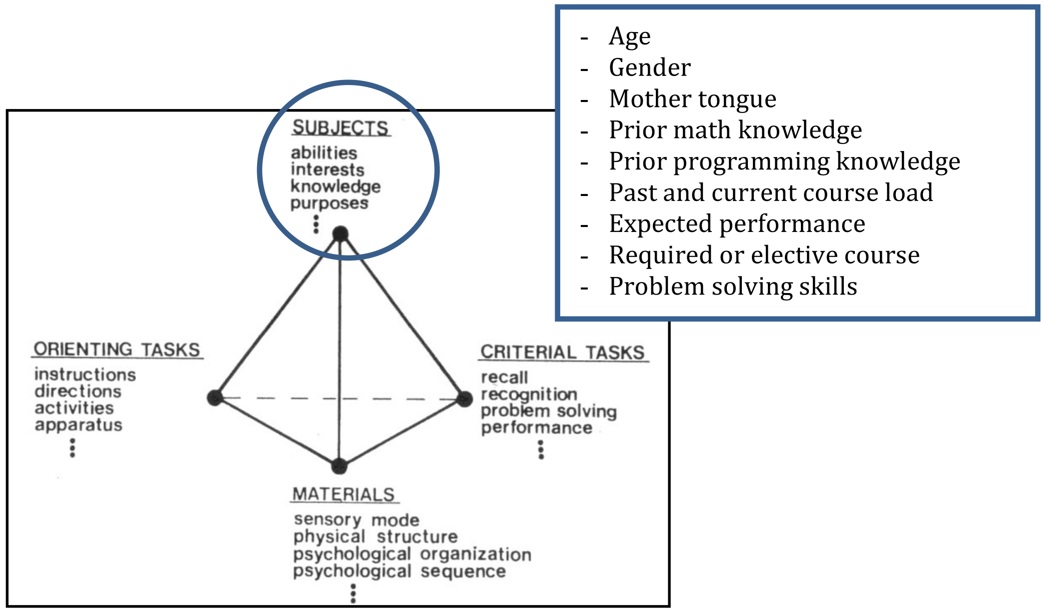

Figure 20. Subjects vertex of Jenkins' Tetrahedron.

Gender. Of the 72 participants 24 (33%) were female and 48 (67%) were male. The W10 evening class had more males (81%) than the F09 day class (58%). Having more males than females in a programming course seems to be the norm (Clarke & Chambers, 1989; Evans et al., 1989; Byrne et al., 2001). Even though the female students' mean scores were higher for test 2 and the final exam, the difference was not statistically significant. Table 12 displays the scores on the three summative evaluations for both genders and the results of independent t-tests for each summative evaluation. Evans et al. (1989) reported that in their study female students' outperformed male students. Kay (1992) reported that "in 15 of 32 cases, males had higher aptitude levels than did females, although on 12 of the 32 measures there was no difference between males and females in computer aptitude. On only 5 occasions did females surpass males in computer aptitude." Byrne et al. (2001) reported "no significant performance differences for male and female students (p. 50).” This study supports the no-difference in performance between genders finding.

Table 12

Performance on summative evaluations itemized by gender.

		N	Mean	Std. Deviation	*t*	Sig (2-tailed)
Test1	Male	48	74.64	15.57	.54	.594
	Female	24	72.54	16.13		
Test2	Male	48	65.16	22.87	-1.00	.320
	Female	24	70.60	19.10		
Final Exam	Male	48	70.70	20.11	-1.04	.302
	Female	24	75.42	13.29		

Age. The majority of the students, 57 of the 72 students (79.2%), were traditional undergraduate students, meaning less than 25 years old, while 15 (19.4%) were non-traditional students, 25 and older who are working on a university degree while having dependents to care for and/or a full time job. Independent-sample t-tests conducted for each summative evaluation to compare the performance of the two age groups revealed no significant differences in performance on any of the summative evaluations.

Mother tongue. Since Concordia University has students from diverse cultures, hence many students whose first language is not English, it was deemed valuable to look at the use of the online tools and test performance of students whose mother tongue was not English. Use of online tools juxtaposed with mother tongue will be handled in the next section where findings based on the log entries will be discussed. In this section we will consider just the variable mother tongue. Out of the pool of 72 participants 42% (30 students) reported that English was their mother tongue, 14% (10 students) reported that French was their mother tongue and 44% (32 students) reported that neither French nor English was their mother tongue. Table 13 shows the breakdown for each term. Even though the French-speaking students' means on the three tests were higher, the differences were not statistically different. A one-way ANOVA analysis of the three language groups yielded a significance level of 0.967.

Table 13

Count of students with English, French and other as their mother tongue each term and the performance of each language group.

	Fall 2009	Winter 2010	Combined (N = 72)	Mean*	SD
English	47% (21)	33% (9)	42% (30)	70.73	17.62
French	16% (7)	11% (3)	14% (10)	72.31	19.53
Other	38% (17)	56% (15)	44% (32)	70.98	15.32

* Mean of two term tests and final exam for the combined data

Full/Part-time student. The majority of the students reported to be full time students, meaning they were enrolled in at least five courses that term. Table 14 reports the exact breakdown of part-time and full-time students for each term.

An independent-samples t-test was conducted to compare performance of full and part-time students. There was no significant difference in term tests and final exam means for full-time (M=71.86, SD=16.60) and part-time students' (M=66.09, SD=17.08); $t(70) = 1.47, p = .16$.

Table 14

Number of full and part time students each term.

	Fall 2009	Winter 2010	Combined (N = 72)
Full Time	84% (38)	89% (24)	86% (62)
Part Time	16% (7)	11% (3)	14% (10)

Programming background. As COMP218 is an introductory-level programming course for non-computer science majors, most students enrolled in the class have limited to no programming background. They are taking this course because it is a required course for their program or as a filler course, but do not necessarily intend to develop real skill as a programmer. When students were asked to indicate whether they had prior programming knowledge 59% (16) of the W10 students reported they did versus only 29% (13) of the F09 students.

Table 15 has a breakdown of the numbers for each term.

Table 15

Number of students each term with and without programming experience.

	Fall 2009	Winter 2010	Total
No programming background	71% (32)	41% (11)	60% (43)
Some programming background	29% (13)	59% (16)	40% (29)

As expected, students with prior exposure to programming (self-reported) performed significantly better on the three summative evaluations than student with no prior programming experience. Table 16 shows the results of ANOVAs for each of the summative evaluations as well as the effect sizes. The effect seems to be larger for test 1 than test 2 which is expected, as students with prior programming knowledge will have been exposed to the material covered in test 1, while the material in test 2 will be new to the majority of students. The effect size is moderate for the final exam as well. Even though the final exam is comprehensive more weight is given to the material covered in the second half of the term reducing the advantage that students with prior exposure to programming might have.

Table 16

General linear model results of the impact of programming experience on performance on term tests 1, 2 and the final exam.

Programming Experience		Mean	Std. Deviation	N	*F*(1, 70)	Sig.	Partial Eta Squared
Test1	No	70.20	15.89	43	6.556	.013	.086
	Yes	79.49	13.82	29			
	Total	73.94	15.68	72			
Test2	No	62.80	21.85	43	4.116	.046	.056
	Yes	73.16	20.30	29			
	Total	66.97	21.71	72			
Final Exam	No	68.65	16.99	43	4.435	.039	.060
	Yes	77.63	18.81	29			
	Total	72.27	18.161	72			

The advantage that students with prior exposure to programming have in this study matches the findings reported by Kolvalina (1983), Butcher and Muth (1985), Evans et al., (1989), Davy, Audin, Barkham and Joyner (2000), Hagan and Markham (2000), as well as Morrison and Newman(2001), that students who have previously been exposed to programming perform better in a CS1 course than those who haven't.

Mathematics background and thinking skills. COMP 218 is typically populated by students enrolled in a mathematics program (42% - 30 of 72) and a mix of other programs (58% - 42 of 72). These results are not surprising as it is a required course for many mathematics and environment science students. It is an elective for all other students. There were more math students in F09 than in W10; this may be due to the course sequence in the program. Table 17 details the breakdown. "The link between mathematics ability and programming is widely accepted, although it's empirical evidence questionable" (Byrne et al., 2001, p.49). Because of its high concentration of math majors it was felt COMP218 would be a good testing ground for the math versus non-math advantage debate in CS1.

This section refers to research questions 6 and 7 which examine the impact of problem solving skills, mathematics background on student performance on summative evaluations. In Jenkins' Tetrahedron this is designated by the edge which joins the Subjects and Criterial Tasks vertices in other words the impact that a student's characteristic have on his/her performance (Figure 21). Three approaches were used to test for the impact of mathematics on performance in the main study.

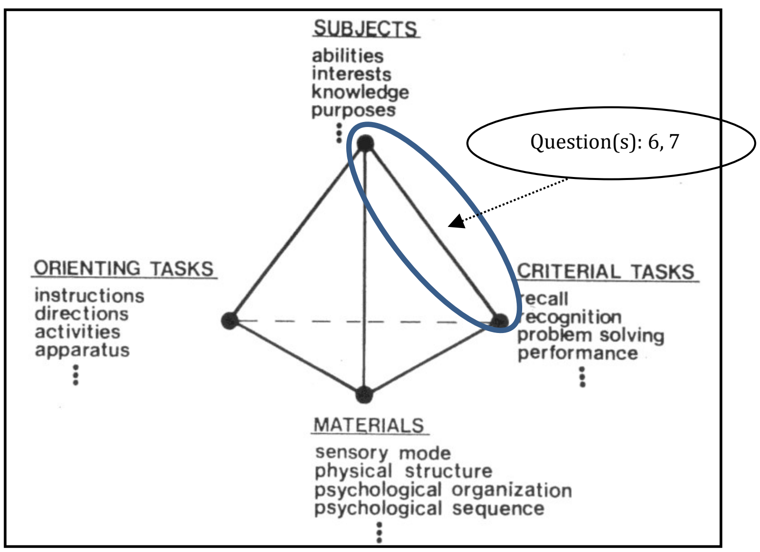

Figure 21. Subjects and Criterial Tasks edge of Jenkins' Tetrahedron.

First approach. The first approach was to classify students based on the program they are enrolled in, the same way it was done for the pilot study. These data were available from the class lists supplied by the university (Table 17). Levene's Test for Equality of Variances resulted in a probability level of 0.39

meaning that the variances of the two groups are approximately equal. The results of an independent-samples t-test revealed no significant difference in overall performance between the students enrolled and not enrolled in a math program; $t(70) = -0.47$, $p = 0.39$. These results are similar to the finding from the pilot study. They do not support the findings reported in the literature that math background is related to performance in programming courses (Butcher et al., 1985; Clark et al., 1989; Evans et al., 1989; Byrne et al., 2001; Wilson et al., 2001; Ventura, 2005).

Table 17

Count of number of students enrolled in a math program and non-math program each term.

	Fall 2009	Winter 2010	Combined (N = 72)	Mean*	SD
Math	47% (21)	33% (9)	42% (30)	72.17	17.06
Other	51% (24)	67% (18)	58% (42)	70.27	16.32

* Mean of two term tests and final exam

Second approach. The second approach, which is new for the main study, was to answer the research question 7 a) which is "Do students with different levels of prior exposure to mathematics perform better in an introductory object oriented programming course than those with limited exposure?" The number of Cegep and university math courses taken prior to COMP218 was used to rank students' math background. Students were asked to indicate from a list of nine possible Cegep math courses the ones they had taken as well as the number of university math courses they had completed (Table 19) . The number of Cegep math courses (Table18) taken by each student was derived from the list of courses they reported completing. Of the 72 students one did not answer these questions.

The more math courses, be they in Cegep or university, taken by students the poorer their performance was. As can be seen in Table 18 , the students with less than three Cegep math courses outperformed those with more mathematics course and the difference is statistically significant; $t(2) = 3.50$, $p = 0.04$. There were six students (of the 71 who answered the questions on math background) who reported having taken less than three Cegep math courses. Of these five reported not having any prior programming experience. So the possibility of having prior programming experience does not skew these findings. Students with four university math (Table19) courses significantly outperformed their peers; $t(2) = 4.23$, $p = 0.02$. Half of these students reported having prior programming experience.

Table 18

Details of students' term tests and final exam means juxtaposed with the number of Cegep mathematics courses taken prior to COMP218.

Number of Cegep math courses taken	N	Mean*	Std. Error
<= 2	6	83.39	9.65
3 to 6	57	51.72	8.61
>= 7	9	43.70	11.92

*Mean of the two term tests and final exam

Table 19

Details of students' term tests and final exam means juxtaposed with the number of University mathematics courses taken prior to COMP218.

Number of university math courses taken	N	Mean*	Std. Error
3 (0 to 3)	19	61.23	7.29
4	22	66.23	7.17
5	31	51.37	7.88

*Mean of two term tests and final exam

A further refinement to the mathematics research question regarding the impact of prior exposure to math course on performance in a CS1 course is addressed by the following research question 7 a)-i: "Does students' prior exposure to specific math courses have an impact on performance in an introductory object oriented programming course?" A univariate analysis of variance revealed no significant impact of any particular math course on performance.

Third approach. The third approach to test for the impact of math background on performance was to look at students' thinking skills. This was to answer the research question 6 a): "Is the level of problem solving skills, regardless of prior mathematics background a good predictor of performance in a CS1 course?"

To test for these skills, all students were asked to complete a seven question quiz, which was a subset of the test used by Mayer et al. (1986) and repeated by Evans et al. in 1989. The questions were classified as problem translation (two questions), procedure comprehension (two questions) and general abilities (three questions). They evaluated analytical skills, attention to details, ability to discriminate and ability to draw inferences. Even though the percentage of variance R-squared was small (less than 9%) students who could follow instructions (question 3 Appendix B) had an advantage over those who could not as far as performance in COMP218 was concerned. Table 20 shows the Pearson's correlation coefficients for question 3 of the thinking skills quiz and each of the summative evaluations.

Table 20

Correlations coefficients and R-squared between ability to follow instructions and performance on assessments.

(N = 72)	r	r^2	p
Test 1	0.276	0.076	0.019
Test 2	0.260	0.067	0.028
Final Exam	0.292	0.085	0.013

Mayer et al. (1986) reported that two thinking skills were predictors of students' success in learning programming skills;

> …ability to translate word problems into equations or answers (problem translation skill), and ability to predict the outcome of a procedure or set of directions that is stated in English (procedure comprehension skill). (p. 608)

Evans et al. (1989) reported that three of the thinking skills tested for were predictors of performance in their study: "the ability to draw analogies" which was evaluated by one of the problem translation questions, "the ability to follow instructions [… and …] spatial relations" (p.1325) which were both part of the general abilities questions. They also admitted that "the predictive power of these three variables taken together was small" (p.1325). In this study the only thinking skill that had some predictive power was the ability to follow instructions.

Math background and expected grade. A final angle considered by the research question 7 b) was whether "… prior mathematics background juxtaposed with expected performance has an impact on performance in an introductory object oriented programming course?" A multivariate analysis with the scores of term tests 1 and 2, and the final exam as predictor variables and expected course grade, number of CEGEP and number of university math courses completed prior to COMP 218 did not result in any significant impact on performance. This study does not match the finding of Rountree et al. (2004) that students' expecting grade at the start of the term (along with other characteristics) had an impact on performance. As no clear indication on how to define a student's math background was found in the literature, three approaches were tried in the main study. The three approaches used to evaluate the impact of math background on performance in a CS1 course are inconclusive and this is in accordance with the literature on math background and performance in CS1 courses, as discussed in chapter 2.

To wrap up the mathematics background and thinking skills discussion in this study student's thinking skill seems to be a better predictor of performance in a CS1 course for non-computer science majors than the number of math courses taken. Consequently, when designing an introductory programming course for non-majors, it might be advisable to administer a thinking skills quiz and to direct students to exercises where they can practice drawing analogies, translating word problem into a mathematical format and following instructions. These should be available at the start of the course to make sure students have the opportunity to brush up on all of these skills and more so the ones they had difficulties with on the quiz.

Summary. Following is a summary of the findings relating to the Subjects (demographic and academic background variables) and Criterial Tasks (performance) edge of Jenkins' Tetrahedron in this study:

- Gender, age and mother tongue have no impact
- Students with prior programming background have an advantage. They scores are higher on all three summative evaluations and significantly better on term test 2.
- Even though three approaches were used to classify a student's math background at the start of COMP218, the findings are non-conclusive. Evaluating students' thinking skills regardless of their math background results in some findings as to the type of skills that would be helpful in COMP218, namely the ability to follow instructions.

Background and academic independent variables introduced to-date. Taking into account all background and academic variables recorded, three multiple regression analyses with the default "Enter" method in SPSS were performed using the sixteen predictors (independent variables listed in Table 21) and the three outcome (dependent) variables which are scores on term test 1, term test2, and final exam to build a predictive model. For the three dependent variables, the initial run was done with all 16 independent variables included. Subsequent runs were performed removing non-significant independent variables but keeping those whose significance was ≤ 0.150 in case one of the non-significance variables is correlated with these marginal ones. For each dependent variable, the final reduced model with the relevant statistics is detailed. Table 22 lists results of the estimates of the equation coefficients of the reduced models as well as the influence on R-squared that each significant independent variable has on the resulting linear model.

Table 21

Sixteen independent variables that might be used to predict computer programming aptitude.

Category	Independent Variables
Background	Age
	Gender
	Mother Tongue (English/French/other)
	Full or part-time student
	Enrolled in math program or not
	Expected grade
Academic	Programming Background
	Number of CEGEP math courses taken
	Number of university math courses taken
	Score on each of the 7 questions from the thinking skills quiz taken from Mayer et al. (1986, p.607)
	Question 1: word problem translation
	Question 2: word problem solution
	Question 3: following directions
	Question 4: following procedures
	Question 5: logical reasoning
	Question 6: spatial ability
	Question 7: verbal ability

Results for dependent variable test 1. Four independent variables best accounted for the variability in a student's term test 1 result: programming background and three problem solving variables (questions 1 word problem translation, 3 following directions and 7 verbal ability) of the thinking skills quiz (F (4, 67) = 6.14, p < .0005). They accounted for approximately 22.5% of the variance in performance on test 1. Programming background had the most impact on the variance at about 8.6% which makes sense as the content covered in the first term test is very basic hence not as much of a challenge for someone who has programmed before. The ability to translate a word problem into mathematical notation and the ability to follow directions were also important skills for term test 1, which are not skills reserved to students with prior exposure to programming.

Results for dependent variable test 2. Only one of the significant independent variables from test 1 accounted for the variability in a student's term test 2 score: the ability to follow instructions, question 3 of the thinking skills quiz (F (1, 70) = 5.06, p =0 .028). It must be noted that it only accounted for approximately 5.4% of the variance. Even though students with prior experience had higher scores on term test 2 with a mean of 73.16 versus 62.80 (F(1,700 = -2.03, p = .046) prior exposure to programming was not a predictor of test 2 scores. This can be explained by the fact that the more advanced students lose their edge once more advanced topics are introduced. As test 2 is held in week 11 of a 13 week term, there is a lot of content that is new even to students with prior programming experience.

Results for dependent variable final exam. When looking at performance on the final exam, five independent variables accounted for any variability in final exam scores (F (5, 66) = 6.11, $p < 0.005$) - programming background and four questions from the thinking skills quiz (question 1: word problem translation, question 2 word problem solution, question 3 following directions and question 5 logical reasoning). They accounted for approximately 26.5% of the variance on the final exam scores. The final exam was designed to evaluate students ability to understand a word problem, design a set of steps that would solve the problem and then to program the solution. The students with prior programming exposure may have had more opportunity to practise these skills.

Table 22

Estimates of coefficients measuring the degree of linear dependence between performance on each summative assessment and the statistically significant independent variables.

Dependent Variables	Independent Variables					
	Var 1	Var 2	Var 3	Var 4	Var 5	R^2
Test 1	Prog. Background	Quest 1	Quest 3	Quest 7		0.225
	0.254	0.273	0.25	0.253		
Change in R^2	0.086	0.071	0.049	0.063		
Test 2	Quest 3					
	0.26		---	---	---	0.054
Final exam	Prog. Background	Quest 1	Quest 2	Quest 3	Quest 5	0.265
	0.254	0.241	0.325	0.299		
Change in R^2	0.06	0.05	0.079	0.085	0.043	

Three observations can be drawn from these results.

1. The most consistent is the low explanatory power of the four linear models less than 27 percent for all three equations. These results are consistent with those of Evans et al. (1989) who used 49 possible predictors, which included demographic, academic, prior computer background and behavioral data, and reported R-square scores of less than 24 percent.
2. A second observation is that few of the independent variables were strong predictors of performance on any of the assessments. In the three models no one variable incrementally accounted for more than a nine percent increase in R-square. This finding is a little higher than the seven percent reported by Evans et al. (1989) in their study which involved students enrolled in a required entry level business computer course. COMP218, it is a required course for some students, while others decide to take it out of interest. The fact that that it was a required course in Evans' et al 1989 study may account for their lower numbers.
3. Finally, in this study the problem solving skills variables as a group seemed to be the "better" set of predictors of student performance as a subset of them were present in the three models. The question that evaluated the ability to follow instructions (question 3) was present in the three models.

In summary, as reported by Bergin et al. (2005) "the factors known at the start of the academic year result in poor predictions of programming performance" (p.415). Similarly Evans et al. (1989) found that "... few of the demographic, academic, computer exposure or behavioural variables were particularly strong predictors of class performance..." (p. 1326). In this study the only characteristics which could serve as an indication of potential performance were the programming background and some of the thinking skills. All other factors known at the start of the term, namely student gender, enrolled program, number of math courses taken at the start of the term are not predictors of performance. It must be noted that COMP218 is intended for non-computer science majors. Many are students who often 'fear' this course and may not be representative of typical computer science majors in terms of their characteristics and computer programming aptitudes.

As mentioned before a recommendation that can be made to instructors and instructional designers of such courses is to include at the start of the term a thinking skills quiz followed by recommendations and the opportunities for students who had difficulties with some of the key questions to practise these skills. They could be in the form of exercises posted on the course web page or even extra tutorial sessions which students would be encouraged to attend to develop these skills at the onset of the course.

Impact of the availability of LTE on attendance. Was student class attendance affected by the availability of slides and lecture captures online? To determine if this was an issue in this study, attendance was taken each class period. About ten minutes after the start of class a sign-up sheet circulated which students were asked to sign. Even though an online representation of the lectures was available, 87% (39) of F09 students and 82% (22) of W10 students attended at least

80% (10.5 weeks) of lectures. *Figure 22* gives the breakdown of percentage of lectures attended by what percentage of students.

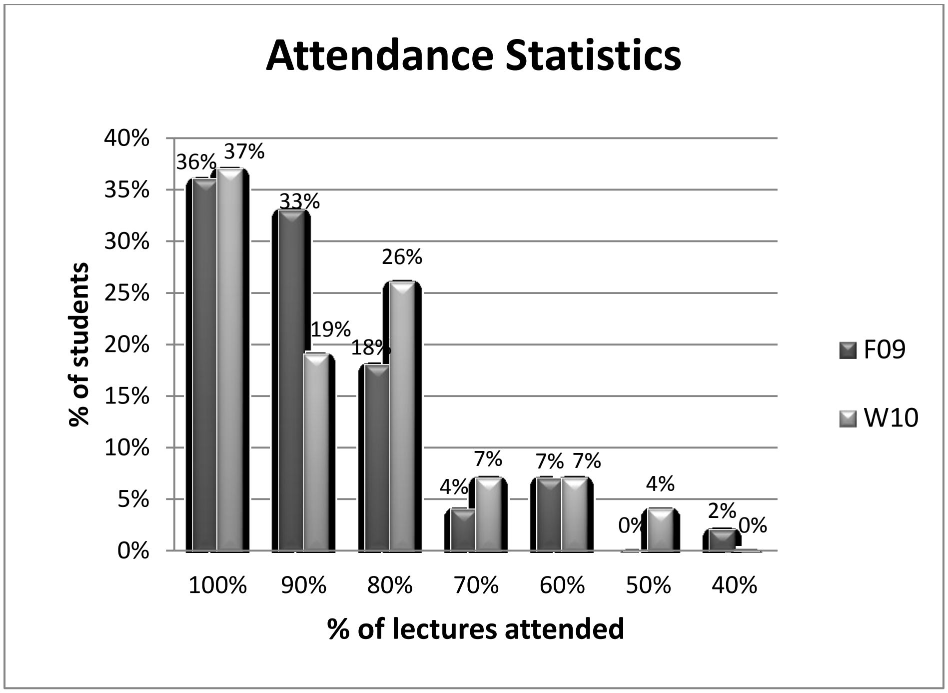

*Figure 22. Statistics on l*ecture attendance.

One point to remember is that the lecture captures were recorded in previous terms (fall 2004 and winter 2005) using the same slides used in F09 and W10. Students who would rely on the lecture captures would get the same content but perhaps not explained exactly in the same way as in the current term. Even though many have speculated that having lecture slides and lecture captures available online would have a negative impact on attendance (Potts, 1993; Bell, Cockburn, McKenzie & Vargo, 2001; Weatherly, Grade & Arthur, 2003; Silverstein, 2006) the results in this study agree with the finding of Brotherton and Abowd (2004) and Davis, Connolly and Linfield (2009) that the availability of lecture captures did not affect attendance. Perhaps "other attendance factors—such as the time of day of the class, the lecture topic, or the engagement level of the professor—

might dominate" (Brotherton et al., 2004, p.147) students' decision on whether or not to attend class. For COMP218 class evaluations were high, perhaps indicating that students saw the value of the F2F interaction and realized that the information presented in class could reduce their study efforts (Van Etten, Freebern & Pressley, 1997). As will be demonstrated briefly in this study, students used the online resources not to replace the classroom learning but to supplement it.

Comparing the performance of F09 and W10 students. Was there a difference in the performance between F09 and W10 students? The reason for this question is to determine if for some of the analyses, the two groups can be pooled into one. Care was taken to make the term tests of both section of comparable difficulty. The same final exam was used for both sections. Table 23 reports the performance of both groups on the three main summative evaluations. The performance of both groups is comparable and independent t-tests showed no statistically significant difference between the two groups on any of the evaluations. For some of the analyses to follow, the two groups will be pooled into one.

Table 23

Students' performance on summative evaluations each term.

	F09 (N = 45)	W10 (N = 27)
Term test 1	Mean = 73.84, SD = 14.40	Mean = 74.10, SD = 17.90
Term test 2	Mean = 67.72, SD = 22.98	Mean = 65.72, SD = 19.77
Final Exam	Mean = 72.45, SD = 17.38	Mean = 71.96, SD = 19.73
Average of two term tests and final	Mean = 71.34 , SD = 16.92	Mean = 70.59 , SD = 16.55

Correlations between term tests and final exam. The performance on in-class formative evaluations, i.e., two term tests and final exams, are statistically significantly correlated. In other words, performance on test 1 is a predictor of performance on test 2 and the final exam, and similarly performance on test 2 is a predictor of performance on the final exam; Table 24 shows the exact correlation values. In this study when evaluating performance we will consider the average of the two term tests and final exam.

Table 24

Correlation between performance on the two term tests and final exam.

		Test2	Final Exam
Test1	Pearson Correlation	.638**	.686**
	Sig. (2-tailed)	0.000	0.000
	N	72	72
Test2	Pearson Correlation		.798**
	Sig. (2-tailed)		0
	N		72

As demonstrated above, students' gender, enrolled program, number of math courses taken at the start of the term is not correlated to a student's performance in COMP218. A student's performance on term test 1 is however an indication of how s/he will perform throughout the term. It is at this point that as educators we need to intervene and to recommend strategies that will help a student better their learning hence their performance. We may have more of an insight on the type of recommendations to make, once we complete the analysis, which is to follow, of the relationship of study patterns and performance.

This completes the analysis of the background and academic independent variables. We will now analyse the LTE usage logs.

LTE Usage Type

From the moment students created their account on the LTE, each time they navigate to a page, an entry was created in the log file detailing the log entry number, a session id, the user's login name, the originating page, the destination page and a time stamp comprised on the date and time. There were over 21,000 log entries for the two terms. Of these entries 21.5% (4534) were visits to LO pages while the rest were navigating the site to visit the assignments, term tests, quiz solutions pages as well as content topic pages. Going back to the research questions, question 4 asks, "Which category of web based learning tools, information, cognitive or elaboration do students prefer to use?" In Jenkins' Tetrahedron this question is considering by the edge between the Materials and Criterial Tasks vertices which focuses on which LOs the students are using to fulfil the learning outcomes (Figure 23).

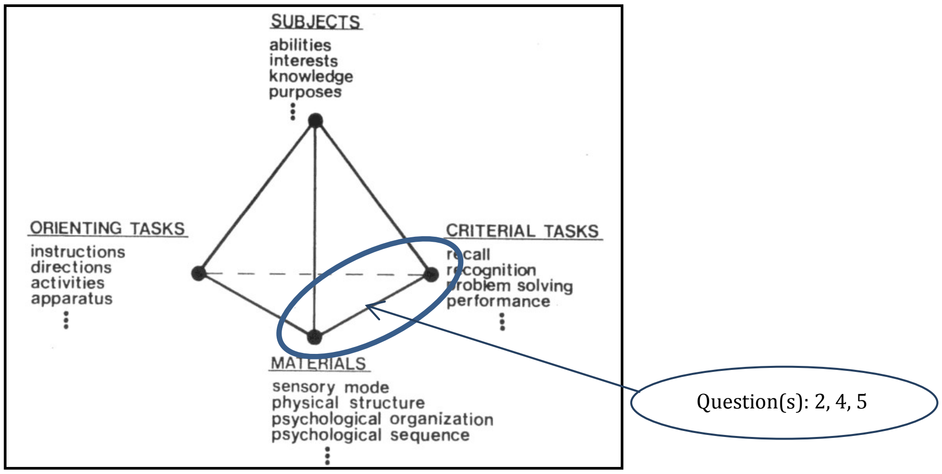

Figure 23. Materials and Criterial Tasks edge of Jenkins' Tetrahedron.

Table 25 gives the details of the types and numbers of LO page visits for each term. The most visited LO tools were the lecture captures, or information tools. Pooling the numbers of annotated slides with voice over (F) and the recordings with the talking head (V) visits, we see that they accounted for 65% in F09 and 66% in W10 of the LO visits to the LTE. These numbers are in accordance with the results reported by Dahlstrom, Walker and Dziuban (2013) regarding tools students wished their instructors used more of. Based on the results of a representative sample of 10,000 from a pool of 113,035 respondents from 47 states and 14 countries, the top tool that 71.5% of the 10,000 undergraduate students wished their instructors used more is lecture capture (p.22). The other feature students wanted to see more of, were "problem sets, sample questions, and related resources (p.23)." Looking at Table 25 again, we see that 30% of the LO visits were to the online formative quizzes, hence practise exercises (elaboration tools). It appears this is what students are saying they want to learn with and are in fact using when available. A question that we will address when looking at the LTE users specifically further down is whether it is just a few students who are availing themselves of the LOs or if they are being used by most students. In other words are there a few keeners using the LOs or are they being used by the majority of students.

Table 25

Details of access to each LOs each term.

Log Entries	FO9 - 15591				W10 - 5497			
LO Entries	3693 (24% of F09 entries)				841 (15% of W10 entries)			
Breakdown of LO Entries	F	V	S	E	F	V	S	E
	1910	525	114	1144	418	134	41	240
	52%	14%	3%	31%	50%	16%	5%	29%

F = Annotated slides with voice over **V** = F with talking head

S = Simulations **E** = Formative online quizzes

The next section will look at the type of learners encountered in the main study, how they used the LTE and what impact it had on their performance on summative evaluations which is the side of Jenkins' Tetrahedron delimited by the Subjects, the Materials and the Criterial Tasks vertices (*Figure 24*).

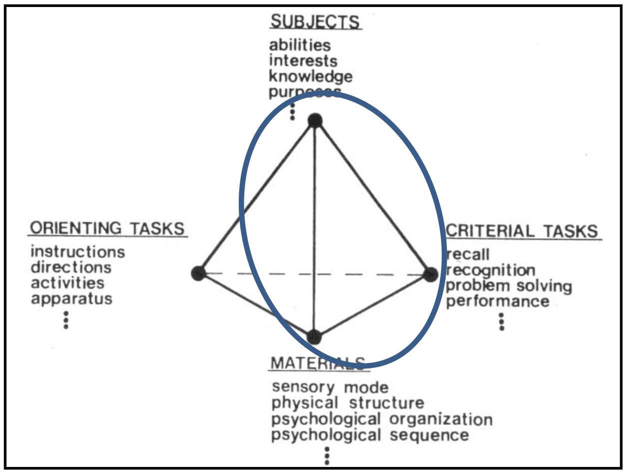

Figure 24. The Subjects, Materials and Criterial Tasks side of Jenkins' Tetrahedron.

Type of learners. As mentioned in chapter 2, the design of COMP218 lends itself well to the possibility of five types of learners (Figure 25) with respect to the use of LTE; the true-F2F learner, the F2F-repository learner (F2F-Rep), the F2F-hybrid learner, the blended learner and the online learner. The true-F2F learner comes to class and does not make use of any of the electronic resources, be it the documents in the repository or the multimedia tools. The F2F-Rep learner is a F2F learner who takes advantage of the documents in the repository. The F2F-hybrid learner is a F2F-Rep learner who also makes use of the LTE multimedia tools to supplement his/her learning. The blended learner, like the F2F-hybrid learner, employs the LTE mainly to supplement in-class learning, but unlike the F2F-hybrid learner, the blended learner misses more classes and relies on the repository and the LTE tools for the missed content. Finally the online learner attends few classes and learns mainly through the use of the documents in the repository and the LTE.

In the main study there was no true-F2F students, which is not surprising as students today are digital natives. As in the pilot study there were no online learners in the main study; it must be noted that the design of the course did not favor a student to be an online learner as the quizzes were now a required component of assessments unlike in the pilot study where they were optional. As attendance was high in the main study, like the pilot study, there were predominantly F2F-Rep and F2F-hybrid learners and some blended learners.

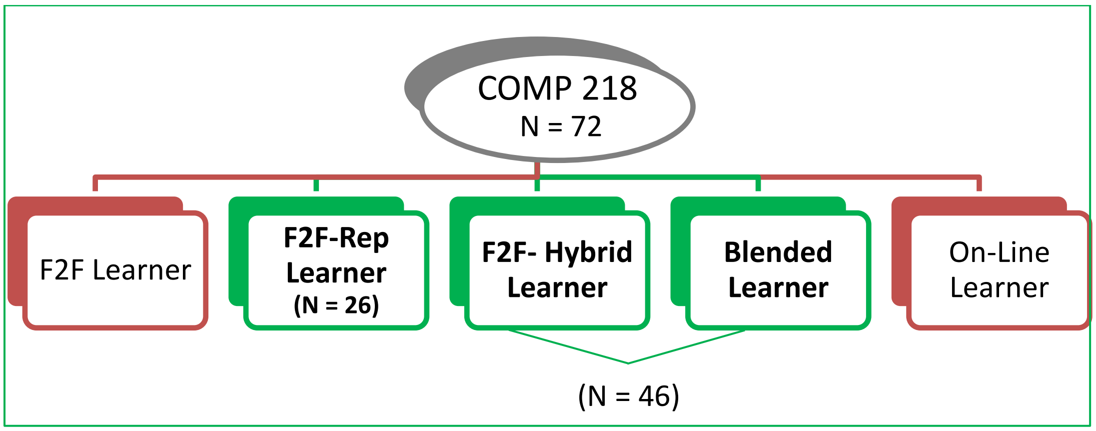

Figure 25. Five possible types of learners in COMP218.

An interesting observation is that the design of COMP218 allowed students to change from one type of learner to another throughout the term. Looking at the use of LTE up to term test 2, 31% (14) of F09 students and 44% (12) of W10 students were F2F-Rep learners, in other words they did not log any time on the LOs in the LTE. In F09, 18% (8) of students were F2F-Rep learners throughout the term; for W10 we don't know how many students were F2F-rep learners for the entire term due to technical difficulties encountered the last three weeks with the log file. In both terms many students started off as F2F-Rep learners and became F2F-hybrid or blended learners. In F09 31% (14) and in W10 11% (3) of students did not make use of the LOs prior to test 1 but did for test 2. As the LTE is a "non-embedded support" tool (Clarebout, et al., 2006), students were not locked into being a specific type of learner. They could adjust as they saw fit and the data demonstrates that they took advantage of this flexibility. Of the 46 F2F-hybrid and blended learners, 30% (17) did not make use of the LOs for test 1, hence were F2F-rep students, and became F2F-hybrid or blended learners after test 1.

Why did these 17 students change from one type of learner to another? Is it due to their performance on term test 1? Table 26 shows the mean scores for tests 1 and 2 for the F2F-Rep learners (NoTst1NoTst2) and the converted students (NoTst1YesTst2). Based on the results of an independent samples t-test, there is no significant difference in performance between these two groups for test1; $t(40) = 1.276$, $p = 0.210$. However, students who made use of the LTE LOs when preparing for test 2 saw their performance drop. An independent samples t-test shows that this drop is statistically significant; $t(40) = 2.199$, $p = 0.034$. For the final exam, again the scores for the F2F-Rep learners were higher than those who used the LOs for test 2 but the difference was not statistically significant; $t(40) = 1.596$, $p = 0.118$. When the performance of the remaining students was compared to the F2F-Rep and converted students they also saw their scores drop for test 2 but the drop was not statistically different. As test 2 is a more difficult exam, it is not surprising that most students' scores were lower for this exam. So the use or non-use of the LTE multimedia tools doesn't seem to be correlated with performance on test 2. The question that cannot be answered is whether the performance of students who used the LTE multimedia tools to prepare for the second term tests would have been worse had they not used the tools.

Table 26

Summary of means and standard deviations of performance on summative evaluations for F2F-rep and converted learners.

Use of LOs	N	Test 1 Mean	Test 1 SD	Test 2 Mean	Test 2 SD	Final Exam Mean	Final Exam SD
NoTst1NoTst2	25	75.68	17.11	70.82	19.61	75.49	15.84
NoTst1YesTst2	17	68.79	17.31	56.40	22.61	66.58	20.27

The next question as a result of these findings is why does the use of the LOs in the LTE seem to have a negative impact on performance? Perhaps it is the way students are using these tools.

How is the LTE being used? The LTE environment has two sections: a repository section and a collection of LOs section. The repository section holds lecture slides (PDF and PPT format), assignment handouts (PDF format) and solutions (text file), and quiz solutions (PDF format). The collection of LOs includes two versions of lecture captures, a Flash version of annotated and narrated slides, and a Streaming version of the annotated and narrated slides with the instructor's talking head on one side, interactive Flash simulations and formative online quizzes. All students in the study made use of the LTE but what resources they used and how they used them differ; 36% (26) only used the repository while 64% (46) used both the repository and the multimedia tools.

As can be seen in Table 27, the repository only users outperformed the repository and multimedia users in all formative evaluations and for test 2 the difference was statistically significant (t(70) = -2.102, p = .039).

Table 27

Performance on summative evaluations of repository users vs. repository and LTE LO users.

Group Statistics						
	Repository Only	N	Mean	Std. Deviation	t	Sig. (2-tailed)
Test1	yes	26	74.70	18.15	0.308	.759
	no	46	73.51	14.29		
Test2	yes	26	73.96	18.72	2.102	.039
	no	46	63.02	22.46		
Final Exam	yes	26	77.03	16.67	1.694	.095
	no	46	69.58	18.59		
Mean of term tests and final	yes	26	75.23	15.58	1.927	.058
	no	46	66.67	19.36		

F2F-Rep users: Repository-only users. One of the research questions (2 b) is: “For those who don’t use the multimedia tools, why are they not using the tools?” To answer this question, in week 11, before the second term test, students were asked to tick off all of the reasons they did not use the multimedia tools in survey 2. Of the 16 F2F-Rep students who answered this question, 25% (4) reported that they didn't find the video lectures/narrated slides necessary in addition to class and 69% (11) reported that they didn't have time, that readings assignments and exams occupied all of their time. A higher percentage of F2F-Rep students, 58% (15 of 26) versus 30% (14 of 46) of non F2F-Rep students reported having prior programming experience which may explain why the F2F-Rep students didn't feel the need to use the multimedia tools.

When looking at the pattern of use of the repository, two patterns emerged: a frequent and a less-frequent access pattern. A student who accessed the slides on a regular basis and looked at the quiz and assignment solutions as they became available was considered a frequent user, while a student who went to the repository less than 6 weeks during the term was considered a less-frequent user. This classification considers the weeks of access and not the specific type of document accessed each week or the number of time each document was viewed. Figure 26, the access pattern of student F09_37, shows that this student visited the repository weekly to view/download slides, quiz solutions or assignment solutions, consequently is considered a frequent user. Figure 27, access pattern of student F09_45, who visited the documents in the repository 2 weeks out of the 16 weeks in the term including the 3 weeks between the end of class and the final exam, is considered a less frequent user. Both of these figures report the number of times each student visited the slides, quiz and assignment pages on a weekly basis.

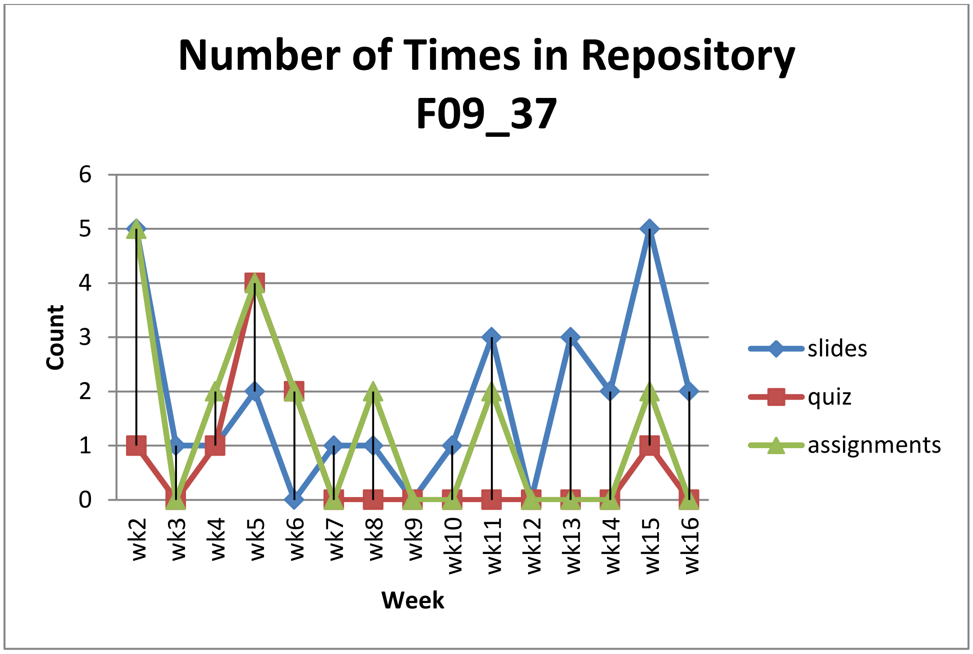

Figure 26. Access pattern of student F09_37, a frequent repository user.

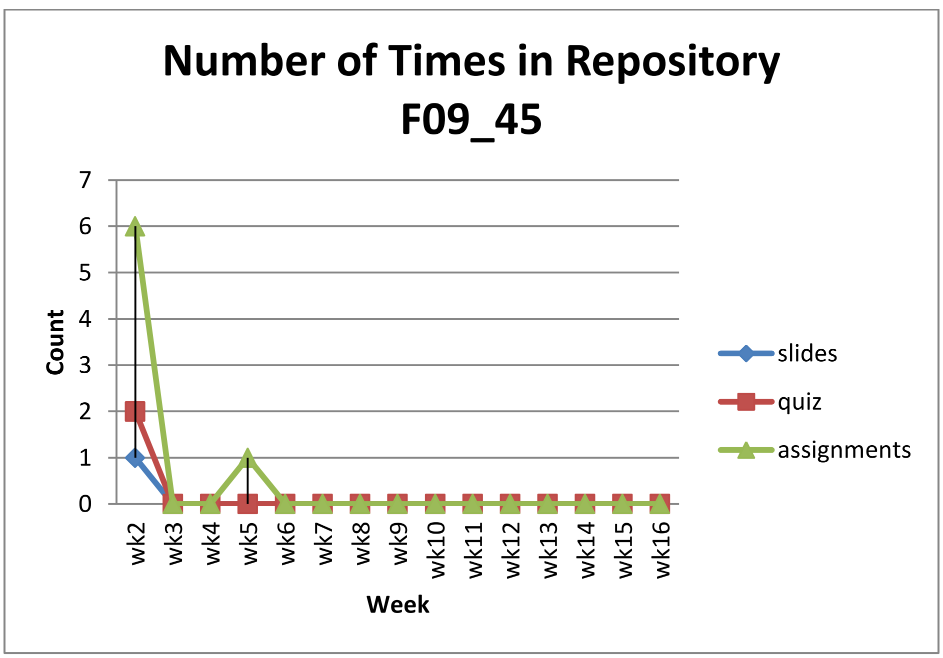

Figure 27. Access pattern of a student F09_45, a less- frequent repository user.

Of the 26 F2F-Rep users, 31% (8) were frequent users while 69% (18) were less-frequent users (*Figure 28*). Even though the mean scores of the two term tests and final exam of the frequent users (M=77.82) was higher than the less-frequent user (M = 74.08), the difference was not statistically significant. It must be noted that the slides for the entire term were available the first week of classes. Each week students were told which set of slides we would be covering. Some students may have downloaded or viewed the slides as they needed them, while others may have opted to downloading more than one set when they went to the repository which is a possible explanation for the frequent and less-frequent access patterns for the repository only users. Assignment solutions were available after the due date and quiz solutions after the quiz was taken. Again, some students may have gone to the repository to download solutions as they were available while others may have gone in the week before evaluations and downloaded them all at once. It must be noted that just because a student downloaded a solution doesn't mean they actually looked at it right away. They may have consulted them only when they were preparing for the next summative evaluation. Their access patterns to the resources in the repository may not accurately reflect their study patterns.

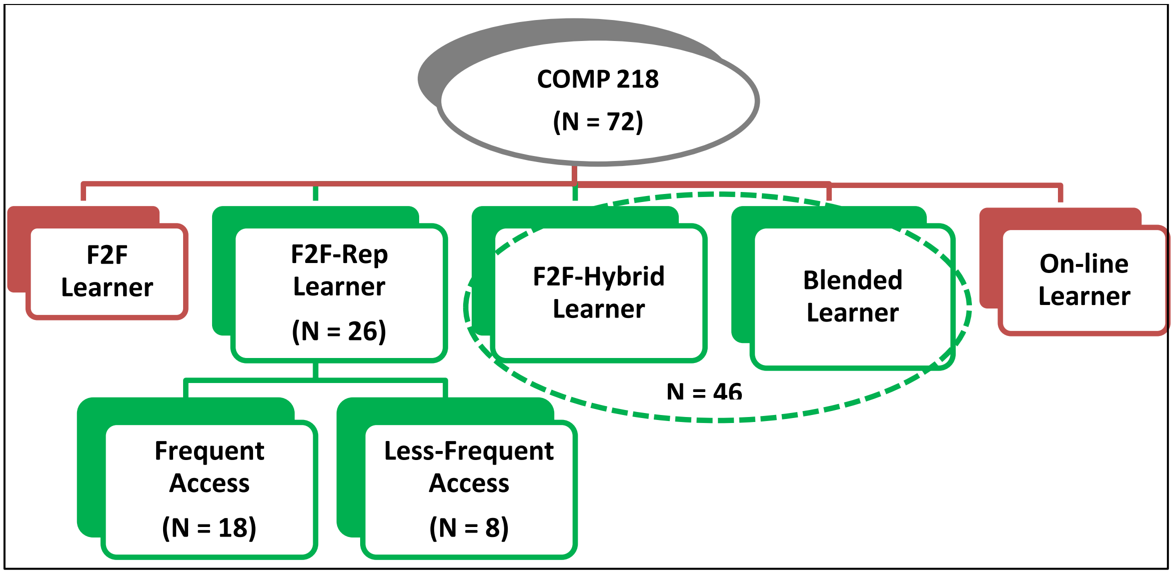

Figure 28. Access pattern of F2F-Rep learners.

The other resource the F2F-Rep students had access to was the textbook. In the survey just before the second term test (in week 11), students were asked about their use of the textbook. Of the 26 students, 25 answered this question. Table 28 summarizes students' responses.

Table 28

F2F-Rep students' responses to questions about their use of the textbook.

Regarding the textbook, which statement(s) is true?

	FALSE		TRUE	
Before test 1, I didn't have a copy of the textbook, but bought one after test 1	25	(100%)	0	(0%)
Before test 1, I didn't have access to a textbook but did after test1	25	(100%)	0	(0%)
Since test1, I still did not buy a copy of the textbook and still do not have access to one	21	(84%)	4	(16%)
I used the textbook to review for term test 2	16	(64%)	9	(36%)
I plan on using the textbook to review for the final exam	9	(36%)	16	(64%)
After test1, I used the textbook to do the recommended exercises	22	(88%)	3	(12%)
After test1, I used the textbook to supplement the classroom material	18	(72%)	7	(28%)

Following are observations regarding the use of the textbook by the F2F-Rep students. It would appear that 84% (21) students bought the book or had access to one for term test 1. Nine reported using the textbook for the second term test. Did these nine use the textbook to prepare for test 2 because their performance on test 1 was poor? It doesn't appear so as these students' scores ranged from 15/100 all the way to 95/100 on test 1. When F2F-Rep students were asked about their planned use of the textbook when preparing for the final exam 64% (16) reported that they were planning on using it. So even though they didn't use the textbook when preparing for test 2, an extra seven were planning to when preparing for the final exam. This implies that 39% (10) of the F2F-Rep students who responded to the question on their use of the textbook felt the textbook was not a worthwhile resource; they had not used the textbook when reviewing for either of the term tests and were not planning on doing so for the final. Seven of these students reported having some programming knowledge before COMP218. This may explain why they felt they didn't need the extra resource. Two students added comments regarding the textbook. Student F09_15 (scored an A in the course and had no prior programming background) said "I bought the textbook, but kind of never use it". Student W10_06 (scored an A+ in the course and had programming background) said "bought the textbook but did not open it yet, not planning to". These numbers seem to suggest that 39% of the F2F-Rep students were confident that the material in the repository and class were sufficient for them.

As a closing comment on the F2F-Rep students, more than half had prior exposure to computer programming, which may explain why many of them felt they didn't need to use the LOs in the LTE. Of those students who reported on why they did not use the LOs, the most common reason given was a lack of time. Time management may be an issue for these students and a study guide may be a welcomed resource.

F2F-Hybrid and blended students: repository and LOs users. Two aspects of the interaction of the F2F-hybrid and blended students use of the repository and LOs will be looked at: what students are using the LOs for and their usage pattern of the repository and LOs.

Which multimedia tools in the LTE are most popular? One of the research questions (Q4) is "which category of web based learning tools, information, cognitive or elaboration, do students prefer to use?" To address this question a count was made of the number of students using each of the digital resources. The narrated slides (information tools) had the largest following with 91% (42) of the 46 F2F-hybrid and blended students using them. The second most popular was the online-exercises (elaboration tools) with 67% (31) of the students making use of them. The videos, the second type of information tools, were not as popular as the narrated slides but were still viewed by 59% (27) of the students. The least popular were the simulations (cognitive tools) but were still viewed by 50% (23) of the students. The most popular tools were the information tools. Almost all F2F-hybrid and blended students (45 of 46) made use of either or both formats of the lecture captures. Again this matches the findings reported by Dahlstrom et al. (2013) that lecture captures are a favored tool by undergraduate students.

Did these students use the textbook as well as the LTE LOs? Of the 46 students, 37 reported on their textbook use. One student stated that s/he didn't have a copy of the textbook before the first test but that s/he bought one after. Only 14% (5) of the 37 reported using the textbook for test 2 and 24% (9) were planning on using the textbook when preparing for the final. The textbook doesn't seem to have been favored by the students. Comments from the students confirm this:

- "the textbook was useless compared to LTE". (Student F09_10)
- "textbook is useless in this class, hardly ever use it online notes suffice". (Student F09_31)
- "so far the textbook has been useless, any information I need I can look up in my notes or slides or even Google examples because it is faster than trying to find it in a book". (Student F09_36)
- "I have the textbook but have never used it because studying from the slides and attending classes and tutorials are more useful and enough to know the material". (Student W10_08)
- "bought the book, read at beginning of term but from the video and slides I understand better, not very helpful the book". (Student W10_25)

This matches the findings of Subholk (2007) who reported that in his study "approximately 80% of the students made less use of the textbook to varying degrees since video lectures were available" (p. 76). As we are dealing with digital natives, who grew up with technology, a hardcopy textbook is not as appealing to them as digital lecture captures. Even though both are passive media, recordings have moving components and a human voice which they are more receptive to. The digital native students are more inclined to search for information on their wireless devices than in a hardcopy textbook. This seems to suggest to instructional designers and instructors who are planning on adopting a textbook for their course, that they should consider an electronic version with incorporated search features instead of hard copy ones.

Distinguishing characteristic of LOs available in the LTE. One of the main differences between the LOs available to student is the level of activity required to use them. The videos and annotated slides (information tools) can be classified as passive tools as students listen and/or watch the recorded explanation given by the instructor. The only interaction they have with this LO is to start and stop it, go back to listen to an earlier segment, advance to a later segment and listen to it whenever they want, where ever they want and as often as they like allowing them to review challenging content as often as they need to. "In contrast to passive media, active media provide an interactive resource that students can use to test and build their understanding" (Bell et al., 2001, p.2). The active tools in the LTE are the online quizzes (elaboration tools) and simulations (cognitive tools). Following are the research questions (question 1) which deal with the use of the different categories of tools which will be addressed next:

1. Do students who use multimedia learning tools designed for specific cognitive skills via the course web page to complement a F2F class perform better than those who don't?

    a) Is there a relationship between the use of "information tools" (annotated slides with audio, annotated slides with audio and video) to review the modeling of algorithm development and student performance?

b) Is there a relationship between the use of "cognitive tools" (interactive Java applets) to visualize the execution of code segments and student performance?

c) Is there a relationship between the use of "elaboration tools" (online quiz and paper-pencil exercises) for self-assessment and student?

Information (passive) LOs users. Looking at the use of the passive information tools (lecture captures) 17% (8) of the F2F-Hybrid and F2F-Blended students used these types of tools exclusively. Of these 8, only one reported planning on using the textbook to prepare for the final exam. The remainder did not acknowledge even owning or having access to a textbook. As far as prior programming experience, 5 of the 8 reported having some exposure before COMP218. The course score for these students ranged from A+ to D: 1 A+, 4 in the Bs, 1 in the Cs and 2 in the Ds. The students who scored in the Ds both attended less than 75% of the F2F lectures (50% and 66%).

Active LOs User(s). One student used <u>only</u> active tools, the online quizzes (elaboration tool). S/he reported having a copy of the textbook but never using it, attended every lecture and did not report having any prior programming background. His/her final course grade was an A.

Active and passive LOs users. The majority of the students, 80% (37 of the 46 F2F-Hybrid and F2F-Blended students), used a combination of active and passive LOs; the passive LOs, information tools, to acquire the knowledge and the active LOs to evaluate their understanding of the material. There were no unique characteristics as far as textbook use is concerned or attendance. The course grades ranged from the A to F.

Difference in performance. Research question 1, was concerned with the impact that the use of the different types of LOs might have on specific cognitive skills. On Jenkins' Tetrahedron this is the base of the pyramid which encompasses the Orienting Tasks, the Materials used and the Criterial Tasks, the desired learning outcomes, vertices (Figure 29).

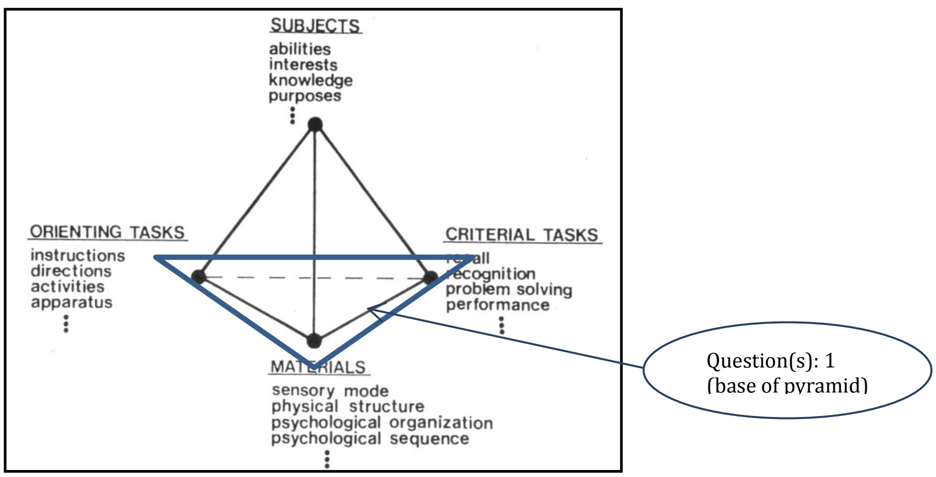

Figure 29. Base of Jenkins' Tetrahedron

There was no correlation between the use of the active, passive or both with performance on the two term tests and final. Even though *Figure 30* shows that the active user outperformed the other users, this result does not have much value, as there was only one student in this category.

Even though the differences are not significant, students who used both active and passive LOs outperformed the passive LOs only users in term test 2 and the final exam. More of the passive users had prior programming experience (63%, 5 out of 8), while the reverse is true for students who used both the active and passive LOs (24%, 9 out 37 has prior programming experience). So even though the use of the LTE LOs did not result in significantly higher scores on summative evaluations, perhaps as Brotherton et al. (2004) reported maybe it allowed students to study more efficiently and to narrow the gap in performance between the students with and without programming exposure.

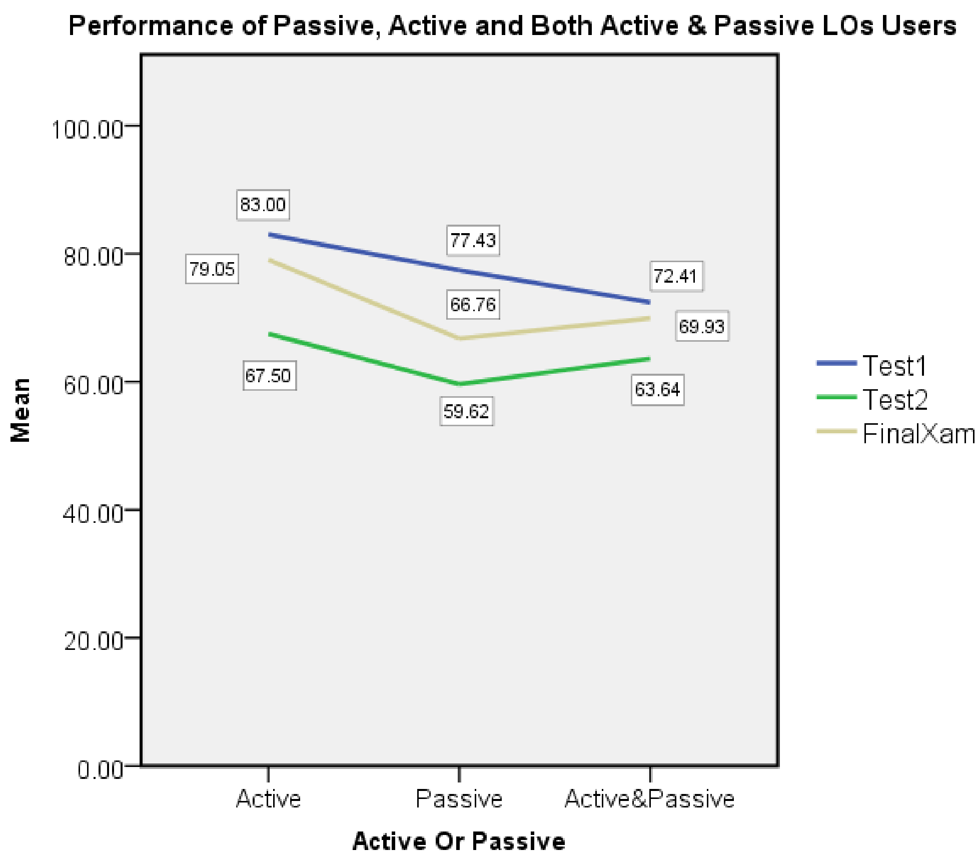

Figure 30. Mean of summative evaluations for F2F-Hyrid and F2F-Blended learners based on their use of active and/or passive LOs.

Considering only the students who had prior programming exposure in both groups, there is a significant difference in performance. Table 29 summarizes the means and standard deviations for both groups. A one-way ANOVA revealed that the difference in performance for term test 2 is statistically significant ($F(1, 12) = 7.29$, $p = .019$). The scores on the final exam for students with prior programming background who used the active and passive tools was higher but not significantly higher than those who used only the passive tools ($p = .07$).

Table 29

Performance on term test 2 and final exam based on use of active/passive LOs for students with CS background.

Type of LOs used	Term Test 2		Final Exam	
	Mean	Std. Dev.	Mean	Std. Dev.
Passive	57.83	17.85	64.75	27.23
Passive and Active	80.11	13.00	83.50	8.36

To summarize, the impact of the use of the LOs on student performance on summative evaluations is as follows:

- Q1 a) The use of the (passive) information LOs alone did not have an impact on performance.
- Q1 b) There were no students who used only the (active) cognitive LOs.
- Q1 c) There was only one student who used the (active) cognitive LOs. No findings can be reported.
- Looking at the more general question (Q1) of whether the use of the LOs had an impact on performance, students with prior programming background

and who made use of both the passive and active LOs, significantly outperformed their peers who relied only on the passive LOs.

What are hybrid students using the passive (narrated and video) tools for? Research question 2 specifically asked "What are the students using the tools for? To revisit concepts which are not mastered yet? To prepare for an exam? To prepare for an upcoming class"? Even though 45 students used the narrated and/or video, only 36 specified what they used them for. The main reason was to review in preparations for exams. Students were asked to check off all reasons that applied. Table 30 list the reasons and their frequencies.

Table 30

Reasons students are using videos and/or narrated slides (N = 36).

	Video	**Narrated**
To review lectures in prep for exam	18 (50%)	15 (42%)
To keep current	12 (33%)	9 (25%)
Make up occasional missed class	8 (22%)	9 (25%)
Instead of going to class	0	2 (6%)

Reviewing for exams was also one of the most important reasons (75%) given by engineering students in Davis' et al, (2009) study. The number one reason (85%) was "to recap difficult concepts (p.69)." *To keep current* in our study is probably an equivalent reason. The low numbers of students who reported viewing the videos or narrated slides instead of going to class, supports the finding of Davis'

(2009) study, where all students reported that having the online lectures did not change how often they attended class, meaning that they didn't decide to skip a class because they could see the recording of it at a later date but instead knew that if they had to skip a class, they could make it up. Students who are taking advantage of the recordings are doing so to supplement and not to replace F2F class time. This supports one of Dahlstrom's et al. (2013) reported findings that "students continue to say they prefer and learn the most in courses with some online and some face-to-face components. (p.38)"

As Concordia University has a large population of students whose mother tongue is not English, the use of the annotated slides by these students alone compared to students whose mother tongue is English was looked at. Did the non-English students use this tool more? Even though the difference in use between the two categories of students is not significantly different, it is interesting to note that the non-English students spend on average 3 more hours on the annotated slides with voice over with or without the talking head than students whose mother tongue is English. Though the difference is not significant, students have told the researcher that they weren't as stressed about not understanding some English words during class as they knew they could review segments they missed the meaning of after class.

Why did some students not use the narrated or video slides? Research Question 2 b) specifically asks for those not using the multimedia tools, why are they not using them? Of the 30 who reported not using the narrated slides or videos, 33% (10) said that they didn't find the video/narrated slides necessary in addition to class implying that they felt they were getting all the information necessary for their learning by attending class. Did these students actually attend most of the lectures to be able to make such a statement? Tabulating the attendance numbers of these students, 14% (4) missed at most the equivalent of one week of classes, 70% (21) missed the equivalent of two to three weeks of classes, and only 16% (5) missed more than 3 weeks of classes. As 84% (25) of the students attended at least 3/4 of the lectures, it is fair to say that they are in a position to judge whether the lectures seemed to have met their learning needs.

Another reason students could check off for not using the video/narrated slides was that they did not have the required connection or processing speed to do so. Only 10% (3) reported this as the reason. This matches the finding of a 2012 study by Carder, Gatlin-Watts and Rubach (2012) who surveyed University students from Canada, Mexico, United States (US), Belgium, France, Finland, and Spain and found that "most students owned their own computers (85.6% and above), and most (86.0% and above) had Internet access outside of their university (p. 69)." In the 2013 report by Dahlstrom and his teams report, they found that students not only had access to the Internet outside of their institution, but that they "typically owned at least two Internet-capable devices (p.38)." As course designers' and instructors, we don't need to worry about students' abilities to access online resources anymore.

The last reason students could check off for not using the video/narrated slides was that they didn't have time, that reading, assignments and exams occupied all their time; 63% (19) reported this as the reason. The majority (83%-25) were full time students, hence taking at least five courses. Better time management is an issue that most universities today are attempting to help their students with. Many offer workshops or even a full term course on time management. At Concordia, the Counselling and Development Centre offers time management workshops throughout the academic year to help students organize their study time.

Students had the option of adding a reason of their own to explain why they did not avail themselves of the video/narrated slides. Only one student mentioned that he had technical difficulties viewing the videos.

Is both the narrated and video version of lectures necessary? The creation of the narrated/annotated (Flash) slides is much simpler and quicker than the videos (Video) which are a combination of the narrated/annotated slides and the talking head. Which did student use most? This is a question worth exploring as the videos require more time and expertise hence money to produce. Most educators can manage the capturing of their lectures on their own with a PC-tablet and the appropriate screen capture software. Producing the videos with the talking head and annotated slides requires more know-how and resources. When looking at the pattern of use of the Video and Flash slides it appears that the Flash slides were more popular. Table 31 summarizes students' use of Videos versus Flash. Of the 45 users of the Flash and/or Video version of the slides, 76% (34) used the Flash version exclusively or started with the Video version and switched to the Flash version versus 8 (18%) who used the Video version exclusively or started with the

Flash and switched to the Video version. The addition of the “talking head” didn’t appear to add any value to the recordings. In future terms, the video version will be dropped by the researcher and more focus will be given to the annotated and narrated interactive digital videos which can be viewed in a FLASH and HTML5 environment.

Table 31

Count of use of video and/or flash lecture captures.

	N (out of 45)	%
Flash only	26	58%
Video only	3	7%
Started with Video then went to Flash	8	18%
Started with Flash then went to Video	5	11%
Mix of Flash & Video	3	7%

To summarize:

- Students who made use of only active or active and passive LOs had higher scored on term test 2 than students who used the passive LOs.
- Hard copy of textbook is not a popular passive tool.
- Lecture captures are used as an addition to F2F class time and not to replace it.

- The version of the lecture captures without the talking head was the version the students viewed most. The talking head version of the annotated and recorded slides, which have a much higher overhead to produce, don't seem to be worth the extra production resources.
- Effective time management seems to be an issue for many students, hence providing study guides to students at the start of the term may direct them towards more effective study habits.

Frequency of class time and frequency of use of LOs. When I tabulate the average number of times students in F09 and W10 accessed the three types of LOs (combined the two types of lecture capture LOs) prior to term test 1, the evening students (W10) used the lecture capture more than twice as frequently as their peers in the day section from the previous term, but when preparing for the second term tests students in both group used them as frequently. Similarly, each W10 student accessed on average the online exercises at least 5 times, but the F09 students each accessed it on average once. For the other LOs and the rest of the term there are no differences. The researcher expected the F09 day students to access the LOs twice as often since they met twice a week, while the evening students met only once a week. But this did not occur and in fact the evening students accessed the LOs much more than the day students prior to term test 1.Perhaps because they only met once a week, they needed to review the material more often. Even though the frequency of lectures for both groups was different and the time of day in which classes were held was different the performance of both groups is comparable and the frequency with which they accessed the LOs is not that dissimilar either. Since the usage log data for the last three weeks before the final exam in the winter 2010 term are not available (due to technical difficulties), it was not possible to compare the access frequency from term test 2 to the final exam.

Table 32

Number of times the LOs were accessed by students in F09 and W10 sections up to Term Test 2

	Up to Term Test 1			Term Test 1 to Term Test 2		
Terms	Flash/ Video	Exercises	Simulations	Flash/ Video	Exercises	Simulations
F09 (N = 34)	8.7	1.8	0.4	16.9	17.4	2.0
W10 (N = 12)	20.6	5.6	1.6	16.1	13.7	1.8

Usage patterns of the LTE. Why is the performance of students who use the multimedia tools worse than the performance of students who don't? Notwithstanding the result of the use of the LTE and performance, a more careful look at usage patterns allowed us to confirm one perception about students' study habits: many students cram before assessments (Brotherton et al., 2004). Figure 31 shows the percentage of students for F09 and W10 who made use of the resources each week. Remembering that the term tests were written in week 6 and 11, there is a small increase in the percentage of students who made use of the LTE in weeks 5 and 6 and a more pronounced increase in week 10. Similarly, the percentage of F09 students who used the LTE when preparing for the final exam also increased the week leading to the final. Figure 32 and Figure 33 show the minutes logged on LTE weekly in F09 and W10 terms. What is noticeable when looking at these usage graphs are the peaks that occur just before evaluations. The first peak shows students used the LTE to prepare for the first term test. As reported by Brotherton et al. (2004), the second and third peaks provide evidence suggesting that the students found the system useful as a study aid for the first exam and decided to use it even more when preparing for the remaining summative evaluations. If the students did not feel they benefited from the use of the system, the second and third peaks would not have been as pronounced (p.140). This also supports the idea that most students' primary motivation for studying for an exam is to obtain good grades (Van Etten et al., 1997) which is why they cram just before evaluations instead of studying in a more distributed manner.

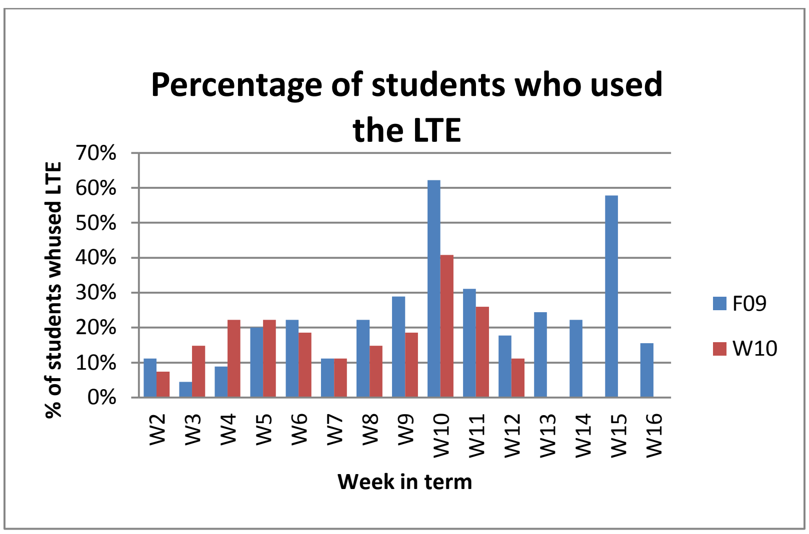

Figure 31. Percentage of students who used LTE each week.

(Data for last three weeks of W10 are not available due to technical difficulties)

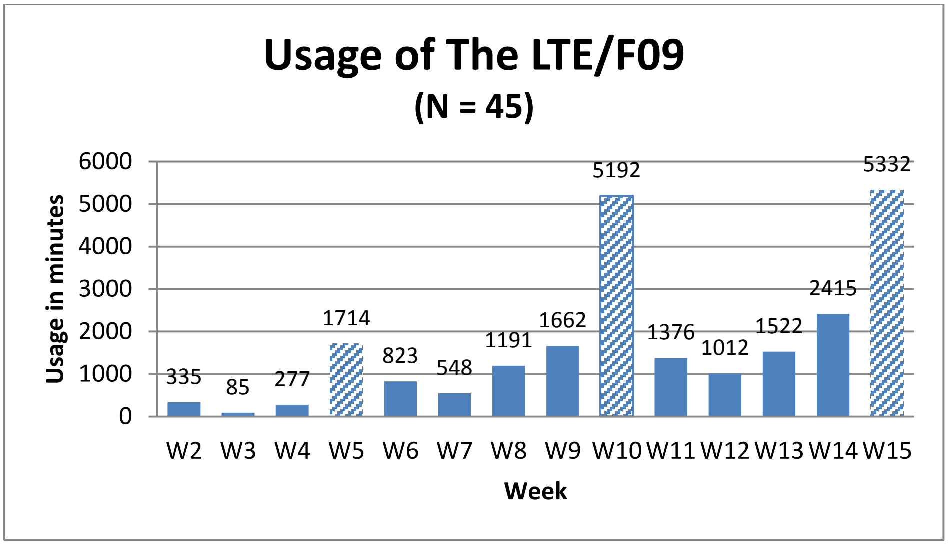

Figure 32. Weekly usage in minutes of LTE by F09 students.

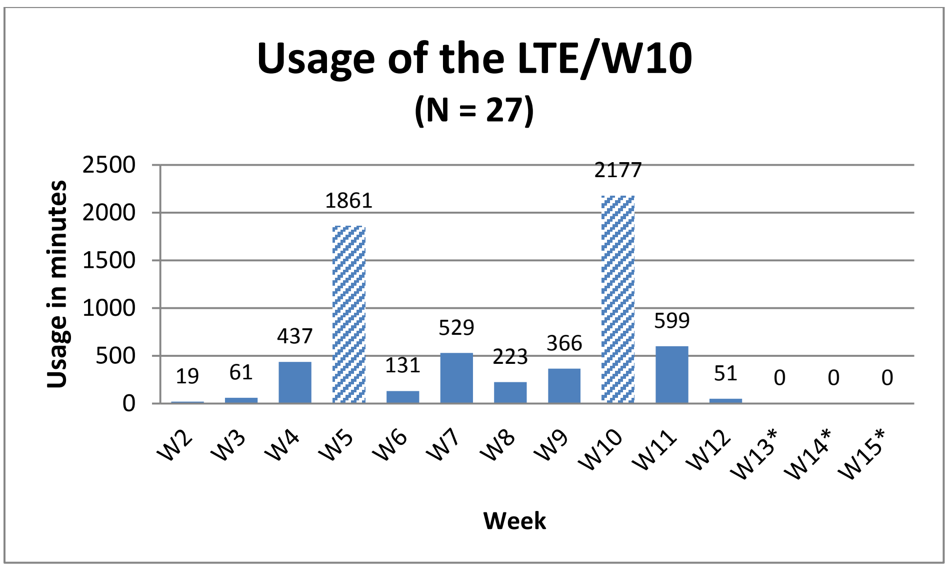

Figure 33. Weekly usage in minutes of LTE by W10 students.

(* Note that there is no usage data for a portion of week 12 to week 15 due to technical difficulties)

Even though there are three peaks, these figures suggest that some students used the LTE in between the peaks. Upon further analysis of the LTE usage patterns, three types of users emerged: the distributed user, the massed user, and the just-once user. Line graphs of minutes spend on LTE for each participant from both terms were produced to help in the classification.

Definition of each type of user. Before discussing the performance of the three types of users, a description of their usage pattern will be given along with a sample usage graph for each to illustrate the patterns.

Massed user. A massed user is one who made use of the LTE predominantly before tests. *Figure 34* shows an example of the usage pattern of a massed user; student F09_36 used the LTE only during weeks 10 and 14 to prepare for assessments which were held in weeks 11 and 16. test.

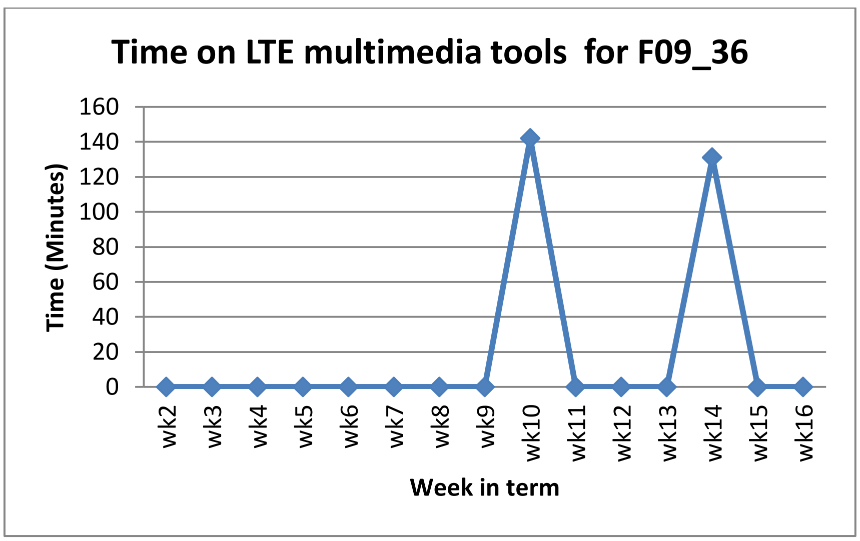

Figure 34. Example of a massed usage pattern of LTE.

Distributed user. A distributed user is a one who made use of the LTE on a more regular basis. *Figure 35* is a line graph of student F09_09 whose usage peaked before each assessment but who still made use of the LOs between assessments as well.

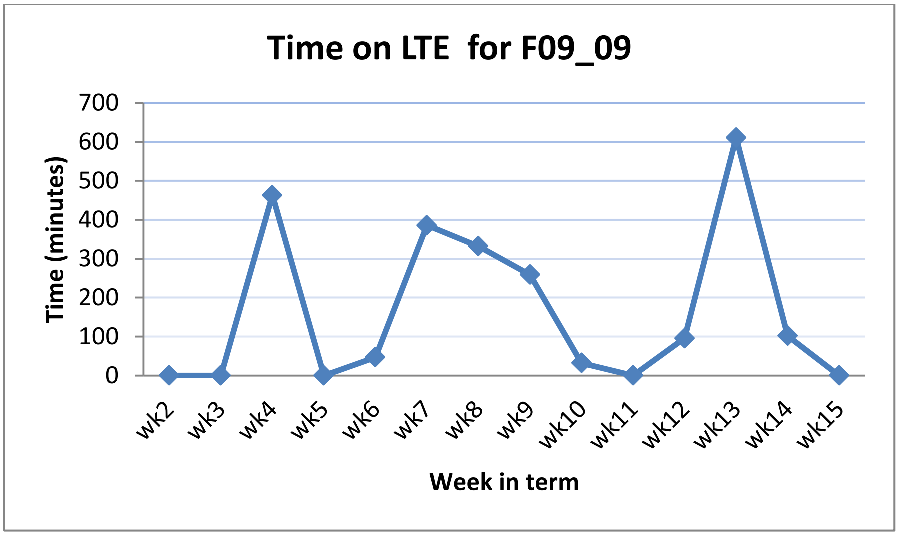

Figure 35. Example of a distributed usage pattern of LTE resources.

One-time user. Finally the one-time user, as its name implies, is a user who used the LOs only once (one day or one week). Figure 36 illustrates the usage pattern of one-time user W10_28.

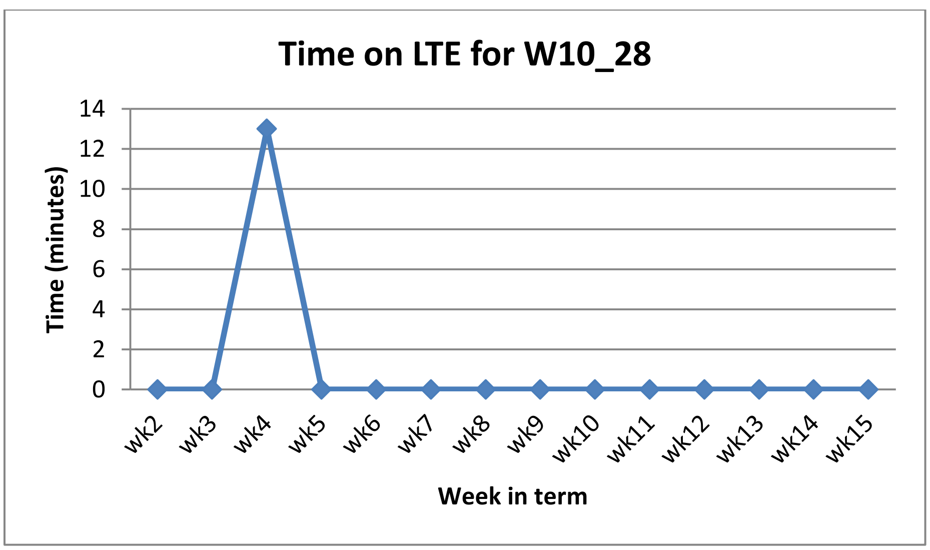

Figure 36. Example of a one-time usage pattern of LTE resources.

The breakdown of the three types of users is as follows (Figure 37): of the 46 F2F-Hybrid and Blended users, 17% (8) were distributed users, 52% (24) were massed users, and 31% (14) were one-time users.

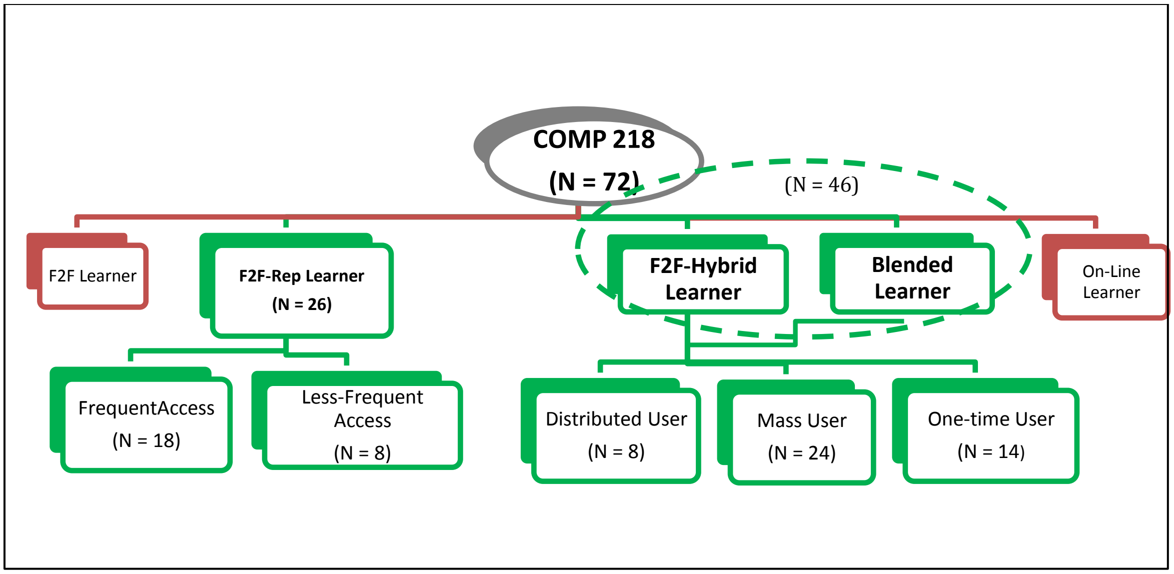

Figure 37. Breakdown of possible access/usage patterns.

Performance of the three types of users. Is there a difference in performance between the three types of users? Figure 38, indicates that the distributed users performed best on the three tests, while the massed users fared worst on the three assessments.

Comparison of mean of assessments
by LTE usage type.

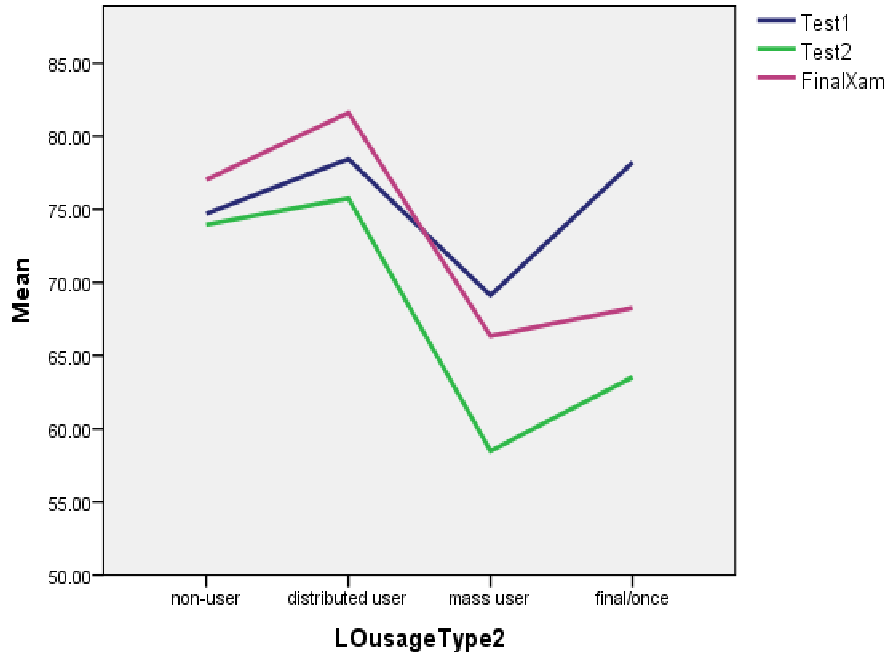

Figure 38. Performance comparison of four types of users.

(Variable LOusageType2 = Learning object usage type)

Are any of these differences statistically significant? After confirming that there was no violation of homogeneity of variance (Table 33), a one way-ANOVA was performed to analyse if any of the differences in performance discussed above were statistically significant. As can be seen in Table 34 there was a statistically significant difference ($F(3,68)= 2.89$, $p = 0.04$) in performance for test2 between the groups of users and the non-users as well as a significant effect ($F(3,68) = 3.65$, $p = 0.02$) for the average of the two term tests and final exam. Tukey post-hoc comparisons of the four groups indicate the non-user group (M = 75.23, 95% CI [68.94, 81.52]) performed significantly better than the massed user group (M =

60.75, 95% CI [51.49, 70.02]), *p =0.024.* Differences between the other groups were not significant. LSD post-hoc comparisons also indicate a significant difference in performance between the non-users and massed users (*p* = 0.005) as well as a statistically significant difference in overall performance between the massed and distributed user groups (*p* = 0.015).

Table 33

Results of Levene's test of Homogeneity of Variance for the different types of users of LTE (non-users, distributed, massed and one-time users).

Test of Homogeneity of Variances

	Levene Statistic	df1	df2	Sig.
Test1	1.367	3	68	.260
Test2	1.031	3	68	.384
Final Exam	.900	3	68	.446
Tests Avg.	1.370	3	68	.259

Table 34

Results of a one-way ANOVA comparing performance for the four types of users.

ANOVA						
		Sum of Squares	df	Mean Square	*F*	Sig.
Test1	Between Groups	991.15	3	330.38	1.37	.261
	Within Groups	16456.38	68	242.00		
	Total	17447.53	71			
Test2	Between Groups	3784.82	3	1261.61	2.89	.042
	Within Groups	29668.00	68	436.29		
	Total	33452.82	71			
Final Exam	Between Groups	2353.81	3	784.60	2.53	.064
	Within Groups	21065.76	68	309.79		
	Total	23419.56	71			
Term Tests and Final average	Between Groups	3351.94	3	1117.31	3.65	.017
	Within Groups	20805.42	68	305.96		

A study by Keppel in 1967 and then repeated by Bloom and Shuell in 1981 showed that students' performance on a test, for which they were required to learn a list of vocabulary words using a massed or distributed practice, was virtually equivalent in the short term but the distributed learners fared better in the long run. As far back as 1968, Sommer wrote that "several questionnaire, interview, and observational studies on a university campus revealed that students believe cramming is most useful in courses which required considerable memorization and is least useful when application, analysis or creativity (synthesis) are called for". The findings in this thesis offer empirical data to support the notion that cramming for an exam that requires more than memorization is not beneficial. As the data shows crammers performance on evaluations was the lowest. Programming requires little memorization hence students who crammed weren't well prepared for the in-class summative evaluations. When learning how to program, one needs to remember the syntax of programming statements and the set of prewritten functions, but the bulk of the aptitudes required are critical thinking and the ability to abstract which are not skills that can be memorized. The evaluations were designed to evaluate students' programming capabilities and not how well they memorized the syntax of programming statements. A study by Brotherton et al. (2004) looked at the use of captured notes which were augmented "with audio and video using the teacher's handwriting, slide visits, and a timeline as indices into the media" (p. 133) used by Calculus students. The evaluation schedule was similar to COMP218's, namely two term tests and a final exam. They also found when looking at the access patterns, that there were "three sharp peaks in access [which] occur[ed] around exam dates" (p.140). It would appear that students' main priority is preparing for summative evaluations and not so much for long term knowledge acquisition.

Did students follow the feedback recommendation? To assist students when reviewing topics they were having difficulties with on the summative evaluations, personalized feedback sheets were appended to each student's graded term tests (test1 for F09 and tests 1 and 2 for W10) highlighting the concepts they should review based on their performance and which tools in the LTE would be beneficial.

Analyzing the log entries to see if the students followed these recommendations was disappointing but instructionally useful. It turns out that most students ignored the suggestions given to them when term test 1 was returned and used the LTE to prepare for the upcoming exam only, meaning they only reviewed the material covered after the first test. As the usage logs for the last 3 weeks of the W10 term are not available the results for each term are presented separately.

Results for F09. Of the 46 F2F-Hybrid and Blended learners, 34 were from the F09 section. Of these students 76% (26) used the LO to prepare for test 2. They reviewed new content covered since test1 in preparation for the second test. Only one student followed some of the recommendations made after test1. When looking at the logs after test2, we see that 31 students used the LOs in preparation for the final exam. Of these 42% (13) used it to review new material only, 6% (2) reviewed new material and reviewed some of the older material, 16% (5) used it only to review specific topics and 36% (11) reviewed everything systematically.

Results for W10. Of the 12 W10 students, they all used LO in preparation for test2, 8% (1) used it to only review material covered in test2, 17% (2) used it to also review new material, while the remaining 75% (9) used it only to review new material. The results for usage after test2 are only partial. However of the 7 students who used it after test2 and up to week 13, all used to it to review material that was presented after test 2 and not to review material prior to test 1.

Summary. In both terms, there was no relationship between performance on test 1 and how students prepared for test 2. It appears that the majority of students used the LOs to prepare for an upcoming exam, disregarding in most cases the recommendations made in the personalized feedback forms attached to their term test 1 and 2. Even though the feedback forms were intended to orient students towards strategies that would help them better manage their study time by helping them focus on the concepts they had difficulties with and LOs which would best serve them, students seemed to have used the LOs mainly to prepare for the upcoming evaluation. This seems to indicate that their efforts are focused on studying for the next evaluations and not so much on mastering the content. This may not be that surprising in this course as most students will probably not take a follow-up programming course. This outcome matches the findings reported by Van Etten and his team in 1997 that “students read and study more for tests in their major (p. 207).” What we cannot verify is if students were using other resources to review the topics that were highlighted for them in their feedback forms, such as help from a friend, a private tutor or other online resources than the ones offered in the LTE. Although many researchers report positive effects for giving advice or encouraging words to students while they are working with the course content (Carrier, 1986; Clarebout et al., 2008; Ross et al., 1981; Kirschner et al., 2006), this study’s data show that students’ didn’t use the study guides attached to their term tests, or if they did, there was no evidence to suggest it.

CHAPTER 5. IMPLICATIONS, LIMITATIONS AND CONCLUSIONS

This final chapter will report on the implications, the limitations and contribution of the findings of this study. This chapter concludes with some recommendations for future research.

Implications and Contributions to Knowledge

This study informs various areas of blended learning course design. The blended learning design proposed in this study allows students to choose the kind of learner they want to be throughout the term ranging from F2F to online or to a blend of the two with the added capability of switching between the different types of learners during the term to sustain their changing academic and/or personal needs. An added advantage specific to 200-level courses is that students are starting with different levels of prior knowledge, so the proposed format allows students with knowledge and/or skill deficits to review content as often and whenever they like. Thus, students can differentially benefit from additional interactive LOs. Following are some implications and/or recommendations as a result of the main findings in this study.

Demographics and academic background. When considering students' demographic and academic backgrounds at the start of an introductory programming course, one characteristic had an impact on performance: prior programming background. As expected students with prior exposure to programing outperformed students with little or no prior exposure. The challenge in teaching introductory courses populated by students with mixed levels of knowledge is to teach at a level that will keep all students' interested and all mastering equally the learning outcomes. However, as an instructor it is advisable to teach at the target audience's level so as not to discourage the novice students, for whom the course is intended while providing thought-provoking and challenging practice problems to keep the more knowledgeable students engaged. It appears that the present design achieved this outcome, as students from all background levels both utilized the LTE, and used it differently, as discussed below.

Thinking skills. Certain thinking skills have been shown in this study to be an asset when learning how to program: following instructions, translating a word problem into a mathematical format and logical reasoning. To identify students' weaknesses in these skills, administering a thinking skills quiz at the start of the term will allow both the instructor and the students identify the skills that students need to further develop. Materials and practice problems, or even optional tutorial sessions can be organized to help students enhance their thinking skills. The results of these measures was not shared with the cohort involved in this study, but an instructor may choose to either administer these measures at the beginning of term, or provide the students with the option to self-check, empowering them to reflect on the outcomes, and study accordingly.

Use of the textbook. Very few students purchased the textbook or used the textbook for this course. The results in this study indicate that today's students prefer to use online resources on the course web site or search the web for information rather than consult a hardcopy of a textbook. Perhaps considering an online version of the textbook with searching capabilities or hyperlinks from the table of contents to specific pages will serve our digital native students better.

Passive versus active learning objects. Some students used the active LOs exclusively while others used a combination of active and passive. Related to the backgrounds issue noted above, the students with prior programming background were mainly the active LOs users. This implies that they did not feel the need to listen to the lecture captures as well as attend classes. By attending class they reviewed concepts they had seen before and acquired new knowledge which they followed with the use of the formative online quizzes to evaluate their understanding. The students with little or no prior programming experience used both the active and passive LOs. Even though the active users' scores on summative evaluations were not significantly higher, perhaps the use of the LOS allowed the students new to programming to do better than if they hadn't used the tools, which is why the difference in performance is not statistically significant. With the proposed flexible course design in this study, students were able to use the features whenever they were needed to better their mastery of the course content and to work towards achieving the intended learning outcomes listed in the course outline.

Are the LOs Replacing Class Time? Class attendance was not affected by the availability of the LOs in the LTE. Students reported using them to supplement the in-class experience and not to replace it. Student saw them as a way to review concepts they didn't quite grasp during the F2F meetings, as well as to occasionally make up a missed class. Further this allowed students to be attentive to the learning happening in the F2F meetings, knowing that if they didn't grasp a concept on the spot, they would be able to review it later with different types of LOs. This feature is not typical of the F2F format, even in a blended approach. In short, students didn't need to worry about missing anything, and may very well have taken notes during class such as "review topic X later", at which point they could resume paying attention to the lecture. This support is provided without any extra effort on the instructor's part once the LTE is designed. Additionally, introductory course content tends to remain fairly stable, so significant revisions from term to term are unlikely to be needed.

Usage patterns of the LOs and personalized feedback. Of the students who used the LOs in the LTE, three types of users emerged: the massed user, the distributed user and the one-time user. As reported earlier, in Sommer (1968), no significant difference in student performance was found between those cramming before exams and those interacting with the course content in a more distributed fashion. However, Zimmer and Hovecar (1994) reported significantly higher performance on final examination for the distributed learner. The current study provides empirical evidence to the literature on cramming versus distributed learning in a computer science course. The massed users' or last minute crammers' performance on summative evaluations was significantly lower than the distributed users' performance. The fact that a programming course requires little memorization, and more understanding on how and when to use the different concepts is a point that should be emphasized at the start of the course.

Even though students were given personalized feedback on their term tests, based on the usage logs there are no data to support that they did follow the suggestions. What can't be checked is whether the feedback incited some F2F learners to become blended or hybrid learners after term test 1. Even though they used the tools to prepare for the term test 2 and not to review concepts they had difficulties with in test 1, the fact that they even used the LOs may be partially credited to the feedback and may have lessened the gap between the performance of students with and without prior programming at the start of the course.

Although the 5-minute quizzes administered between term tests were designed to encourage more distributed attention to course content, instructors should consider additional measures to prompt better study habits, such as providing a study guide with recommended study strategies at the start of the course. This approach may serve the students better than attaching recommendations after the summative evaluations on how to catch up once they are having difficulties. This is supported by the findings in Van Etten team's study (1997) where students reported that information on how to study for an examination made their studying and learning easier. So telling students how to prepare for an evaluation by keeping current and not cramming may be better than advising them on how to catch up after the fact. Backing up the suggestions in a study guide with empirical data may add credibility to the claims.

Limitations

The research presented here applies to study habits of non-computer science major students in an introductory computer programming course with a blended course design. The limitations of this study are discussed next.

The primary limitation of this study is the sample size, which is small, and the dependent variables numerous in comparison. The nature of some of the variables namely the LTE usage logs vary significantly across participants which add to the complexity in analyzing the data. The findings reported on the use of the LTE are based on 46 participants, which for some of the analysis is subdivided further into smaller subgroups. The smaller the N size the lower the probability of finding any significant results. That said, even with these constraints, the data yielded findings. This leaves one wondering what other results could have emerged in a similar study with a larger N size, suggesting the need for further research.

A second limitation is the fact that the two sections of COMP218 in this study were held at different time periods of the day and that one section met once a week while the other met twice a week. Even though the two sections were treated as similar and there was no difference in student performance in the two sections, some may see this is a threat to internal validity. The structure and conditions of the two sections was not the same even though both groups ha the same opportunities to interact with the LTE.

A third limitation is that the design of the study was pre-experimental, meaning that there is no real control group. However, a “control group” emerged as the term progressed based on whether students used or not the LTE. There is no way of knowing if students who decided not to use the extra resources did so because of some outside factor not related to COMP218 such as time issues associated with other courses, work and social activities, and if their scores would have been higher had they used the LTE resources. They are invariably non-equivalent, preventing any direct comparison. As noted above, these emergent groups did offer the opportunity to examine relative usage patterns, and their impact on achievement. By preserving the ecological validity of the learning environment, interesting and pedagogically useful outcomes were discovered, a common trait of exploratory research.

Future Research

This study opens the door for more research on blended learning. Following is a non-exhaustive list of possibilities.

A larger sample size, using a multi-institutional quasi-experimental design, would be ideal. The larger sample size would allow for nuances that did not emerge due to the small sample size in the current study to surface and the significance of the ones that did to perhaps be more important. A quasi-experimental design involving more than one university would allow for a control group without fear of contaminating the data on the use of the LTE. One institution could use the LTE environment while another would not have access to it. Care would need to be taken to ensure that the courses in the two institutions are comparable.

It would be interesting to examine CS majors' use of the LTE instead of non-CS majors.. Would the same study patterns emerge? Would the CS majors follow the recommended study guides provided at the start of the term and after each term tests? Since a CS1 course for computer science majors is the basis for the rest of the courses in their program, perhaps they would be more inclined to study for long term learning and not just to pass or do well on the upcoming summative evaluation as non-majors seemed to have done in this study.

Also worth considering are variables related to the students' interaction with a similar environment developed for introductory STEM courses. Could a similar course design be effective in an introductory engineering or mathematics courses which are both similar to a computer programming course in that they require similar problem solving and thinking skills?

Using the same data set, additional analyses could be done looking at the study habits of the different LTE users, namely the massed, distributed and one time users. As these groups emerged as a result of this study, a new study could focus on the finer differences in each group, which was beyond the scope of the study conducted for this thesis.

Similarly a second look at the two types of one-time users individually might offer some insight as to why these students used the LTE only once. In this study the ones who used the LTE just before the final or once during the term were bundled together. A qualitative study would help in understanding the reasons for these students' limited use of the LTE. Did they not make use of the LTE because they felt they didn't need the extra resources or did the resources available not meet their learning needs?

Conclusion

The blended course design which was the focus of this study enabled students to choose between being a F2F learner, a F2F-Hybrid learner, a blended learner and an online learner. Surprisingly enough, the majority of the students chose to be F2F students and used the online LOs to supplement the F2F experience and not to replace it. Students also took full advantage of the unconstrained format of the course by switching at will during the term between being a F2F, F2F-Hybrid and blended learner to meet their changing learning needs.

This design lends itself well to including remediation materials for students who are deficient in some prerequisites or just wanting to review them at the start of the course. It also allows students who are having difficulties with some of the content in the course, to review the instruction as presented by the instructor thanks to the lecture captures as often as they need to and whenever they want. Including online formative quizzes with immediate feedback for each topic of the course allows students to evaluate their learning as well. It gives them control of their learning and the study strategies they want to follow. Similarly this course design lends itself well to including enrichment materials for the more advanced students providing them with the challenge they need to be engaged in the course without affecting the average student's learning.

This course design kills many birds with one stone; it allows students to take control of their learning, to adjust their learning strategy to changing needs throughout the term, to offer remediation tools to those who need them without holding the more advanced students back, as well as offering some challenges to the more advanced students within the context of the course, all in all a win-win course design.

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APPENDIX A. CONSENT FORM

Online Activities to enhance COMP218 Students' learning at Concordia University

As a professor of Computer Science at Concordia University, my goal is to develop effective teaching strategies to help students learn how to master algorithm design and programming. The concept of "blended-teaching", which involves face-to-face and additional on-line learning tools, is a teaching strategy, which I believe COMP218 students will benefit from.

To help explore the effectiveness of these "blends", I am asking your permission to collect information about your learning during this class. More specifically I am asking for your permission to analyze the data I will collect during the term, namely demographic information, your quiz, term-tests and final exam grades and your use of the on-line material to improve this course and future programming courses. I will not know until the end of the term, after I have submitted the final grades, who has agreed to be part of the study. As a result, participating or not has no impact on your final grade and all activities are an integral part of the course.

If you agree to allow me to use the data I collect for my study, I will make sure that the data will be kept confidential, meaning that no one else but me will know the true identity of participating students and I will not disclose this information. The results of this study may be published. Your participation is voluntary; you are under no obligation to take part in this study. The course TA will be collecting the consent forms, placing them in an envelope and delivering them to Ms. Edwina Bowen, one of the administrative assistants in the Computer Science department for safekeeping until the final grades have been submitted. You may choose to discontinue your participation at any time by contacting Ms. Edwina Bowen in the Computer Science Department. Her contact information is on the course website. You can at any time request that the data that you will have provided not be used in my evaluation. **I repeat, your decision will in no way affect your grade in this course.**

I will also be pleased to discuss the results once the study is complete. Any questions or concerns you have with respect to this research should be addressed to Prof. Nancy Acemian (514-848-2424 #7830 or via e-mail at nacemian@cse.concordia.ca).

Thank you,

Student Consent to Participate in Research

This is to state that I agree to participate in data collection for research conducted by Prof. Nancy Acemian. I have read the above description and understand the agreement. I freely consent and agree to participate in the collection of data for this research project.

______ I agree to participate.

______ I do not agree to participate.

Name (please print): ____________________________________

Student ID: ______________________________

I would like a copy of the study findings when they are available ____Yes ____ No

If Yes please give me an email address where you can be reached after the end of the term:

Email: ____

Signature: ________________________________ Date: __________________

APPENDIX B. STUDENT SURVEY 1

STUDENT SURVEY

COMP218/Section F – October 14, 2009

Please take a few minutes to fill out this survey to determine your math background coming into this course and to give me some feedback on your use of the LTE portion of the course web page to date.

Name: ______________________________ **ID**: ________________

Question 1: Gender?

- ☐ Male
- ☐ Female

Question 2: Age?

- ☐ less than 24
- ☐ 25 to 35
- ☐ over 35

Question 3: What is your mother-tongue?

- ☐ English
- ☐ French
- ☐ other (specify) : ___________

Question 4: What program are you in?

- ☐ M.I.S.
- ☐ Mathematics.
- ☐ other (specify) : ___________

Question 5: Do you have previous experience in programming?

- ☐ No, I have never programmed before.

(If you answered "No", move on to Question 7 on the back side of this questionnaire.)

☐ Yes, I have programmed. How well do you feel you know these programming languages?

	Not at all	A little	Well	Very Well
Java				
C++				
Visual Basic				
Other1: (Specify)				
Other 2: (Specify)				

Question 6: Where did you learn most of your programming skills? (Check all that apply)

- ☐ in school (ex. CEGEP, University, professional school, …)
- ☐ on my own
- ☐ through my employment – I have already programmed.
- ☐ other (specify): ____________________

Question 7: Why are you taking COMP 218?

- ☐ It is a required course for my program
- ☐ Is an elective course for my program
- ☐ Out of interest/curiosity
- ☐ Other (specify): ______________________

Question 8: What grade do you expect to get in this course?

- ☐ In the As
- ☐ In the Bs
- ☐ In the Cs
- ☐ <u>Less</u> than C-

Math Background and Problem Solving Questions:

Question 9: Which of the following CEGEP math courses (or equivalent) have you completed?

Check all that apply.

- ☐ Calculus I ☐ Calculus II ☐ Calculus III
- ☐ Linear Algebra I ☐ Linear Algebra II
- ☐ Probability and Stats
- ☐ Finite Math
- ☐ Differential Equations
- ☐ Other(s), please specify: ______________________

Question 10: How many University level Math courses have you taken to date?

- ☐ More than 10
- ☐ 8 to 10
- ☐ 5 to 8
- ☐ 2 to 4
- ☐ Less than 2

Question 11: Are you a

- ☐ Full-time student
- ☐ Part-time student

Question 12: On average how many courses per term have you taken to date?

☐ 6 ☐ 5 ☐ 4 ☐ 3 ☐ 2 ☐ 1

Question 13: How many courses are you taking this term?

☐ 7 ☐ 6 ☐ 5 ☐ 4 ☐ 3 ☐ 2 ☐ 1

Use of the LTE questions:

Please note that we are evaluating the LTE portion of the course web page, not you, so only your complete honesty will help us improve the course and this service.

Question 14: How frequently did you use each of the following course web page/LTE features to date? *Place a check mark ☑ under Never, Sometimes or Frequently for each feature.*

Course Web Page/LTE Features	**Never**	**Sometimes**	**Frequently**
To download the lecture slides			
To view quiz questions and solutions			
To view assignment solutions			
To view lecture videos by topic			
To view narrated slides by topic			
To view the recommended exercises from textbook and solutions			
To do the online exercises			
To practice program segment simulations via the Java applets			
Other (specify)			

Question 15: If you did not make use of the video lectures/narrated slides posted on the course web site, indicate why not (and then move on to Question 18)?

- ☐ Didn't find the video lectures/narrated slides necessary in addition to class
- ☐ Didn't have required processing speed on my computer
- ☐ Didn't have required connection speed on my computer
- ☐ Don't have time; reading, assignments and exams occupy all my studying
- ☐ Other (specify)______________________________

Question 16: a. If you **did** make use of the **video lectures**, for what *purpose(s)* did you view them? *Check all that apply.*

- ☐ To review the lectures in preparation for an exam
- ☐ To keep current with the material
- ☐ To make up the occasional missed class
- ☐ Instead of going to class
- ☐ Other__________________

b. If you had **video lectures** in other courses would you use them?

- ☐ Yes

☐ No

Question 17: a. If you **did** make use of the **narrated slides**, for what *purpose(s)* did you view them? *Check all that apply.*

☐ To review the lectures in preparation for an exam
☐ To keep current with the material
☐ To make up the occasional missed class
☐ Instead of going to class
☐ Other____________________

b. If you had **narrated slides** in other courses would you use them?

☐ Yes
☐ No

Question 18: a. How *useful* do you find the **Recommend Exercises & Solutions**?

☐ Very useful
☐ Somewhat useful
☐ Not very useful
☐ Not useful at all
☐ Not applicable/Did not use

b. If you had **Recommend Exercises & Solutions** in other courses would you use them?

☐ Yes
☐ No

Question 19: a. How *useful* do you find the **On-line Exercises**?

☐ Very useful
☐ Somewhat useful
☐ Not very useful
☐ Not useful at all
☐ Not applicable/Did not use

b. If you had **On-line Exercises** in other courses would you use them?

☐ Yes
☐ No

Question 20: a. How *useful* do you find the **Code Simulation Applets** on the LTE?

☐ Very useful
☐ Somewhat useful
☐ Not very useful

- ☐ Not useful at all
- ☐ Not applicable/Did not use

b. If you had **Code Simulation Applets** in other courses would you use them?

- ☐ Yes
- ☐ No

Question 21: Regarding the textbook, which statement(s) is true

- ☐ I have a copy of the textbook
- ☐ I have access to a copy of the textbook
- ☐ I did not buy the textbook and do not have access to a copy
- ☐ Used the textbook to review for the exam
- ☐ Used the textbook to do the recommended exercises
- ☐ Used the textbook during the term to date to supplement the classroom material
- ☐ Other : ____

Please add any other comments about the content of the course web page/LTE, especially ways to improve them?

____

____

____

____

____

____

____

Solve the following problems as best as you can:

Question 22: A car rental service charges 20 dollars a day and 15 cents a kilometer to rent a car. Find the expression for total cost "C", in dollars, of renting a car for "D" days to travel "K" kilometers.

- ☐ C = 20D + 0.15K

- ☐ C = 15D + 0.20K
- ☐ C = 0.20D + 15K
- ☐ C = 0.15D + 20K
- ☐ None of the above

Question 23: One day Mrs. Arnold worked three-and-one-half hours in the morning, took a one-half hour lunch break, and worked four-and-one half hours in the afternoon. If she began work at 8:30 a.m. what time did she finish?

- ☐ 4:30
- ☐ 5:00
- ☐ 5:30
- ☐ 6:00
- ☐ 6:30

Question 24: Follow the procedure below:

1. Put 5 in Box A.
2. Put 4 in Box B.
3. Add the number in Box A and the number in Box B and put the result in Box C.
4. Add the number in Box A and the number in Box C and put the result in Box A
5. Write down the number from Box A, B and C.

What is the output of this program?

- ☐ 5. 4. 9
- ☐ 14, 4. 9
- ☐ 14, 9, 9
- ☐ 9. 4. 9
- ☐ None of the above

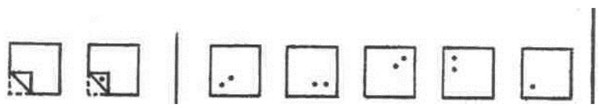
Question 25: Start in the lower left-hand corner and follow the letters up Column 1, down Column 2, up Column 3, and so on until you reach the upper right-hand corner. What is the first letter to appear four times?

	1	2	3	4	5
Row 1	A	B	C	D	E
Row 2	B	D	E	A	C
Row 3	C	E	D	A	B
Row 4	B	A	C	E	D
Row 5	A	C	E	B	D

Question 26: Indicate the set of letters that is different:

BCDE FGHI JKLM PRST VWXY

Question 27: Indicate the correct answer below.



Question 28: Solve the following:

black sheep = dag kip

white dog = tin bud

black cow = dag stam

white sheep = ?

☐ dag kip ☐ tin kip ☐ stam dag ☐ bud tin ☐ tin bud

Thank you! ☺

APPENDIX C. STUDENT SURVEY 2

COMP 218 LTE website

COMP218/Section F – December 7/2009

Please take a few minutes to give your feedback on the content of the LTE portion of the course web page.

Please note that we are evaluating the LTE portion of the course web page, not you, so only your complete honesty will help us improve the course and this service.

Name: ______________________ **ID**: ____________

Use of the LTE questions since TEST 1

Question 1: How frequently did you use each of the following course web page/LTE features to date? *Place a check mark ☑ under Never, Sometimes or Frequently for each feature.*

Course Web Page/LTE Features	Never	Sometimes	Frequently
To download the lecture slides			
To view quiz questions and solutions			
To view assignment solutions			
To view lecture videos by topic			
To view narrated slides by topic			
To view the recommended exercises from textbook and solutions			
To do the online exercises			
To practice program segment simulations via the Java applets			

Other (specify)			

Question 2: Since test 1, if you <u>did not</u> make use of the video lectures/narrated slides posted on the course web site, indicate why not (and then move on to Question 5)?

- ☐ Didn't find the video lectures/narrated slides necessary in addition to class
- ☐ Didn't have required processing speed on my computer
- ☐ Didn't have required connection speed on my computer
- ☐ Don't have time; reading, assignments and exams occupy all my studying
- ☐ Other (specify)_______________________________

Question 3: a. Since test 1, if you **<u>did</u>** make use of the **video lectures**, for what *purpose(s)* did you view them? *Check all that apply.*

- ☐ To review the lectures in preparation for an exam
- ☐ To keep current with the material
- ☐ To make up the occasional missed class
- ☐ Instead of going to class
- ☐ Other_________________

b. If you had **video lectures** in other courses would you use them?

- ☐ Yes
- ☐ No

Question 4: a. Since test 1, if you **<u>did</u>** make use of the **narrated slides**, for what *purpose(s)* did you view them? *Check all that apply.*

- ☐ To review the lectures in preparation for an exam
- ☐ To keep current with the material
- ☐ To make up the occasional missed class
- ☐ Instead of going to class
- ☐ Other_________________

b. If you had **narrated slides** in other courses would you use them?

- ☐ Yes
- ☐ No

Question 5: a. How *useful* do you find the **Recommend Exercises & Solutions**?

- ☐ Very useful
- ☐ Somewhat useful

- ☐ Not very useful
- ☐ Not useful at all
- ☐ Not applicable/Did not use

b. If you had **Recommend Exercises & Solutions** in other courses would you use them?

- ☐ Yes
- ☐ No

Question 6: a. How *useful* do you find the **On-line Exercises**?

- ☐ Very useful
- ☐ Somewhat useful
- ☐ Not very useful
- ☐ Not useful at all
- ☐ Not applicable/Did not use

b. If you had **On-line Exercises** in other courses would you use them?

- ☐ Yes
- ☐ No

Question 7: a. How *useful* do you find the **Code Simulation Applets** on the LTE?

- ☐ Very useful
- ☐ Somewhat useful
- ☐ Not very useful
- ☐ Not useful at all
- ☐ Not applicable/Did not use

b. If you had **Code Simulation Applets** in other courses would you use them?

- ☐ Yes
- ☐ No

Question 8: Since test 1, regarding the textbook, which statement(s) is true?

- ☐ Before test1 I didn't have a copy of the textbook but bought one after test1
- ☐ Before test 1 I didn't have access to a copy of the textbook but did after test1
- ☐ Since test 1, I still did not buy the textbook and still do not have access to a copy
- ☐ I used the textbook to review for term test 2
- ☐ I plan on using the textbook to review for the final exam
- ☐ After test 1, I used the textbook to do the recommended exercises
- ☐ After test 1, I used the textbook to supplement the classroom material

☐ Other : ____________________________________

Please add any other comments about the content of the course web page/LTE, especially ways to improve them?

APPENDIX D. SPF

Concordia UNIVERSITY

Real education for the real world

Office of Research

SGW Campus - GM 1000
t 514.848.2424x4888 • f 514.848.4290

SUMMARY PROTOCOL FORM

UNIVERSITY HUMAN RESEARCH ETHICS COMMITTEE

IMPORTANT:

Approval of a *Summary Protocol Form* (SPF) must be issued by the applicable Human Research Ethics Committee prior to beginning any research project using human participants.

Research funds cannot be released until appropriate certification has been obtained.

FOR FACULTY AND STAFF RESEARCH:

Please submit a signed original plus THREE copies of this form to the UHREC c/o the Office of Research, GM-1000. Allow one month for the UHREC to complete the review.

FOR GRADUATE or UNDERGRADUATE STUDENT RESEARCH:

- if your project is included in your supervising faculty member's SPF, no new SPF is required

- if your project is supported by external (e.g. CIHR, FQRSC) or internal (e.g. CASA, FRDP) funds, the supervising faculty member must submit a new SPF on behalf of the student as per faculty research above. The supervising faculty member MUST be listed as the PI.

- if your project is NOT supported by external (e.g. CIHR, FQRSC) or internal (e.g. CASA, FRDP) funds, the student must submit a new SPF to the relevant departmental committee. Contact your department for specific details.

INSTRUCTIONS:

This document is a form-fillable word document. Please open in Microsoft Word, and tab through the sections, clicking on checkboxes and typing your responses. The form will expand to fit your text. Handwritten forms will not be accepted. If you have technical difficulties with this document, you may type your responses and submit them on another sheet. Incomplete or omitted responses may cause delays in the processing of your protocol.

1. SUBMISSION INFORMATION

Please provide the requested contact information in the table below:

Please check ONE of the boxes below :

☒ This application is for a new protocol..

☐ This application is a modification or an update of an existing protocol:

Previous protocol number (s): __________

2. CONTACT INFORMATION

Please provide the requested contact information in the table below:

Principal Investigator/ Instructor (must be Concordia faculty or staff member)	Department	Internal Address	Phone Number	E-mail
Nancy Acemian	GSU/Computer Science faculty & Educational Technology Phd student	EV-3.153	7830	nacemian@cse.concordia.ca
Co-Investigators / Collaborators		University / Department		E-mail
n/a				
Research Assistants		Department / Program		E-mail
n/a				

3. PROJECT AND FUNDING SOURCES

Project Title:	Use of Web-based Learning Objects in a Blended Learning Environment in an Object Oriented Programming Course:

	Relationship between Use and Performance

In the table below, please list all existing internal and external sources of research funding, and associated information, which will be used to support this project. Please include anticipated start and finish dates for the project(s). Note that for awarded grants, the grant number is REQUIRED. If a grant is an application only, list APPLIED instead.

Funding Source	Project Title	Grant Number	Award Period	
			Start	End
n/a				

---

4. BRIEF DESCRIPTION OF RESEARCH OR ACTIVITY
Please provide a brief overall description of the project or research activity. Include a description of the benefits which are likely to be derived from the project. Alternatively, you may attach an existing project description (e.g. from a grant proposal).

Purpose of study is to evaluate a blended learning approach to teaching a 200 level undergraduate courses. The study aims at discovering the best practices for using such a system and passing this information on to future students.

---

5. SCHOLARLY REVIEW / MERIT

Has this research been funded by a peer-reviewed granting agency (e.g. CIHR, FQRSC, Hexagram)?

☐ Yes Agency: __________

If your research is beyond minimal risk, please complete and attach the Scholarly Review Form, available here:

☒ No http://oor.concordia.ca/REC/forms.shtml

---

6. RESEARCH PARTICIPANTS

a) Please describe the group of people who will participate in this project.

Students in COMP 218/2 Section F – Fall 2009 at Concordia University.

b) Please describe in detail how participants will be recruited to participate. Please attach to this protocol draft versions of any recruitment advertising, letters, etcetera which will be used.

No formal recruitment . All students enrolled in COMP 218 will be introduced to the study and invited to participate.

c) Please describe in detail how participants will be treated throughout the course of the research project. Include a summary of research procedures, and information regarding the training of researchers and assistants. Include sample interview questions, draft questionnaires, etcetera, as appropriate.

This is a regular 200 level lecture based course which meet twice a week in a regular classroom setting. To complement the classroom activities, all students will have access to an on-line environment which contains additional learning tools which they are free to use or not us. These tools include:

- videos of same prof(researcher) covering the same material in previous terms which students can view to review content missed or not understood. The same slides are used so it will be easy for students to follow. Instructor has taught this course for the last 8 years.

- on-line formative quizzes to evaluate their learning on many topics

- interactive visualization tool (applets) to help student understand the flow of computer program code.

- list of recommended exercises from the textbook with solutions.

Students will be given questionnaires during the term :

- one pretest and demographic questionnaire (sample included in appendix A) given 1st week of class.

- short questionnaires asking them how they are using the online environment and why, probaly 2 or 3 during the term Sample questionnaire in Appendix B.

In addition students performance on the two term tests, quizzes and final exam will constitute dependent variables for this study.

Students' activities on the online environment will be stored in log files automatically while they navigate the online environment. Log entries contain the student's name, activity and a time stamp of each online tool used. This will be transparent to the student. This information is recorded for all students during the term.

Once the consent forms are viewed by the researcher/instructor (after the final grades for the course have been submitted) records of students who did not agree to participate in the study, will be deleted. (See section 7 below for details on consent form.)

---

7. INFORMED CONSENT

a) Please describe how you will obtain informed consent from your participants. A copy of your written consent form or your oral consent script must be attached to this protocol. *Please note: written consent forms must follow the format of the template included at the end of this document.*

Students are given a consent form on week 6, the day of the first term test (due to the fact that all students who are staying in the course will be present that day). A copy of the consent form is availablein Appendix C.

The researcher will introduce the research and include the following points:

- Purpose of research and encourage every one to participate.

- The difference between confidentiality and anonymity.

- The assurance of confidentiality. The instructor/researcher will be the only one who can match specific grades and log entries to a specific student. I will never indicate the identity of the students involved in the study.

After the explanation the researcher/instructor will leave the class and the consent forms will be handed out and picked up by someone not involved in the research (most likely a TA). The forms will be placed in an envelop by the TA and sealed by the TA. The TA will then take the envelop to one of the administrative assistants in the Computer Science department for safe keeping until the final grades have been submitted. The administrative assistant will also be the contact person for students who wish to discontinue participation during the study. She will have blank forms. As such, I, as an intructor, will not know until I have submitted the final grades who is participating in the study and who is not.

My consent form is adapted from the one used by Dr. Richard Schmid et. al. in 2000 for the research project entitled “An examination of learning environments using collaborative electronic concept mapping via synchronous and asynchronous computer-mediated communication”.

b) In some cultural traditions, individualized consent as implied above may not be appropriate, or additional consent (e.g. group consent; consent from community leaders) may be required. If this is the case with your sample population, please describe the appropriate format of consent and how you will obtain it.

I do not expect any cultural issues with the individualized consent as applied in 7 a).

---

8. DECEPTION AND FREEDOM TO DISCONTINUE

a) Please describe the nature of <u>any</u> deception, and provide a rationale regarding why it must be used in your protocol. Is deception absolutely necessary for your research design? Please note that deception includes, but is not limited to, the following: deliberate presentation of false information; suppression of material information; selection of information designed to mislead; selective disclosure of information.

No deception is involved, as the use of the online system is for formative evaluation.

b) How will participants be informed that they are free to discontinue at any time? Will the nature of the project place any limitations on this freedom (e.g. documentary film)?

On the course website there will be the name and contact information of the person students need to contact should they wish to discontinue their participation at any time after having signed a consent form. Students will just have to see this person and sign a new consent form, voiding the first one. This will be explicitely stated when passing out the consent forms.

Also those who did not sign a consent form will subsequently be provided with the oppurtunity to do so.

---

9. RISKS AND BENEFITS

a) Please identify any foreseeable risks or potential harms to participants. This includes low-level risk or any form of discomfort resulting from the research procedure. When appropriate, indicate arrangements that have been made to ascertain that subjects are in “healthy” enough condition to undergo the intended research procedures. Include any “withdrawal” criteria.

Researcher is unaware of any possible risks.

b) Please indicate how the risks identified above will be minimized. Also, if a potential risk or harm should be realized, what action will be taken? Please attach any available list of referral resources, if applicable.

See 9 a) above.

c) Is there a likelihood of a particular sort of “heinous discovery” with your project (e.g. disclosure of child abuse; discovery of an unknown illness or condition; etcetera)? If so, how will such a discovery be handled?

Should a student experience difficulties, or should this method detect a learning disability, I would advise the student to stop the use of the online system. I would then encourage the student to seek the help of a professional, which is available to him/her at the university.

---

10. DATA ACCESS AND STORAGE

a) Please describe what access research participants will have to study results, and any debriefing information that will be provided to participants post-participation.

On the consent form students are asked to give an email address if they want to get results of the study.

b) Please describe the path of your data from collection to storage to its eventual archiving or disposal. Include specific details on short and long-term storage (format and location), who will have access, and final destination (including archiving, or any other disposal or destruction methods).

Logs of use of on-line system:

Initial logs are stored on ENCS servers. The logs (text format) will be downloaded to the instructor's/researchers computer on a weekly basis by the researcher. They will be handled by the instructors/researchers only and viewed by the researcher's committee members. Names will be recoded to insure confidentiality.

Grade sheets are handled by the instructor/researcher and a final copy is send to the department. This is common practice for all ENCS courses. The names of the students and IDs will be replaced by a code to ensure confidentiality. when this information is being viewed by the instructors/researchers committee members.

Attendence sign-up sheets, will be viewed by instructor/researcher only. Instructor has always engaged in this practice regardless of research. The information will be entered in an excel spreadsheet with names replaced by codes again to ensure confidentiality when this information is being viewed by the instructors/researchers committee members.

---

11. CONFIDENTIALITY OF RESULTS

Please identify what access you, as a researcher, will have to your participant(s) identity(ies):

☐	Fully Anonymous	Researcher will not be able to identify who participated at all. Demographic information collected will be insufficient to identify individuals.
☐	Anonymous results, but identify who participated	The participation of individuals will be tracked (e.g. to provide course credit, chance for prize, etc) but it would be impossible for collected data to be linked to individuals.
☐	Pseudonym	Data collected will be linked to an individual who will only be identified by a fictitious name / code. The researcher will not know the "real" identity of the participant.
☒	Confidential	Researcher will know "real" identity of participant, but this identity will not be disclosed.
☐	Disclosed	Researcher will know and will reveal "real" identity of participants in results / published material.
☐	Participant Choice	Participant will have the option of choosing which level of disclosure they wish for their "real" identity.
☐	Other (please describe)	

If your sample group is a particularly vulnerable population, in which the revelation of their identity could be particularly sensitive, please describe any special measures that you will take to respect the wishes of your participants regarding the disclosure of their identity.

Researcher has been teaching COMP 218 for 8 years and is unaware of any vulnerability.

a) In some research traditions (e.g. action research, research of a socio-political nature) there can be concerns about giving participant groups a "voice". This is especially the case with groups that have been oppressed or whose views have been suppressed in their cultural location. If these concerns are relevant for your participant group, please describe how you will address them in your project.

n/a

---

12. ADDITIONAL COMMENTS

a) Bearing in mind the ethical guidelines of your academic and/or professional association, please comment on any other ethical concerns which may arise in the conduct of this protocol (e.g. responsibility to subjects beyond the purposes of this study).

none

b) If you have feedback about this form, please provide it here.

none

---

13. SIGNATURE AND DECLARATION

Following approval from the UHREC, a protocol number will be assigned. This number must be used when giving any follow-up information or when requesting modifications to this protocol.

The UHREC will request annual status reports for all protocols, one year after the last approval date. Modification requests can be submitted as required, by submitting to the UHREC a memo describing any changes, and an updated copy of this document.

I hereby declare that this Summary Protocol Form accurately describes the research project or scholarly activity that I plan to conduct. Should I wish to add elements to my research program or make changes, I will edit this document accordingly and submit it to the University Human Research Ethics Committee for Approval.

ALL activity conducted in relation to this project will be in compliance with :

- ***The Tri Council Policy Statement: Ethical Conduct for Research Involving Human Subjects*, available here:**

  http://www.pre.ethics.gc.ca/english/policystatement/policystatement.cfm

- **The Concordia University Code of Ethics: Guidelines for Ethical Actions**

Signature of Principal Investigator: ______________________________

Date: ______________________

APPENDIX F: SAMPLE CONSENT FORM TO PARTICIPATE IN RESEARCH

Consent must be obtained from any study participant. Written consent forms must follow the format of this form (exceptions may be given to multi-institutional projects). Oral consent scripts should include the same information. Please adapt this template to suit your project. Language should be at no more than a grade eight reading level. If you are using written consent forms, note that participants should be given two copies of the consent form – one to keep, and one to sign and return to the researcher.

CONSENT TO PARTICIPATE IN (*RESEARCH PROJECT TITLE*)

This is to state that I agree to participate in a program of research being conducted by (*Name of Researcher*) of (*Name of Department*) of Concordia University (*contact info including phone and e-mail).*

A. PURPOSE

I have been informed that the purpose of the research is as follows … (*Please state the purpose of the research clearly and concisely, in no more than one or two sentences).*

B. PROCEDURES

Indicate in this section where the research will be conducted and describe in non-technical terms what the subjects will be required to do, the time required to do it, and any special safeguards being taken to protect the confidentiality or well being of the subject.

C. RISKS AND BENEFITS

Indicate in this section all potential risks of participation, and any benefits of participation.

D. CONDITIONS OF PARTICIPATION

- I understand that I am free to withdraw my consent and discontinue my participation at anytime without negative consequences.

- I understand that my participation in this study is (*pick appropriate word*):

CONFIDENTIAL (i.e., the researcher will know, but will not disclose my identity)

OR

NON-CONFIDENTIAL (i.e., my identity will be revealed in study results)

- I understand that the data from this study may be published.

OR

I understand that the data from this study will not be published.

I HAVE CAREFULLY STUDIED THE ABOVE AND UNDERSTAND THIS AGREEMENT. I FREELY CONSENT AND VOLUNTARILY AGREE TO PARTICIPATE IN THIS STUDY.

NAME (please print) ______________________________

SIGNATURE ______________________________

If at any time you have questions about your rights as a research participant, please contact Adela Reid, Research Ethics and Compliance Officer, Concordia University, at (514) 848-2424 x7481 or by email at areid@alcor.concordia.ca.

APPENDIX E – EXAMPLE OF COMPLETED FEEDBACK SHEET

Comp 218/Fall09 **Feedback Sheet for Test 1**

Name: _

Following are some recommendations for you based on your performance in Term Test 1.

Question 1- I suggest you:

- ☑ Read in your textbook pages 194-205(4th Edition) or 186-189, 205-211 (5th Edition)
- ☑ Review slides 20-30 of Strings/Library functions slides available slides available in the Lecture Presentation Slides section of LTE.
- ☑ View the lecture in either format available on the Selection page in the Course Topic section of LTE
  Logical Operators/Statements
- ☑ Test your understanding by completing the on-line quiz in the Selection page in the Course Topic section of LTE
- ☑ Practise by doing the recommended exercises listed the Selection page in the Course Topic section of LTE

  Recommended exercises in textbook (page numbers in () are for 5th edition, others are for 4th edition)
  # 5, 6 p. 241 (232)

Question 2 – I suggest you:

- ☐ Read in your textbook pages 101-107 (4th Edition) or 98-102 (5th Edition)
- ☑ Review slides 18-23 of Real Numbers, explicit/implicit type conversion slides available slides available in the Lecture Presentation Slides section of LTE.
- ☑ View the lecture in either format available on the Built-In Data Types page in the Course Topic section of LTE.
  Arithmetic Operators
- ☑ Practise by doing the recommended exercises listed on the Built-In Data Types page in the Course Topic section of LTE

  Recommended exercises in textbook (page numbers in () are for 5th edition, others are for 4th edition)
  Exam Preparation Exercises: # 7 p. 134 (129) a) to c), e), g)
  Programming Warm-Up Exercises: # 3, 6 a) to d) p.136 (131)
- ☐ Test your understanding even further by attempting exercises
  #2, 4, p 136 (4th edition) / #2, 4 p. 131 (5th edition)

Question 3 - I suggest you:

☑ Read in your textbook page 74 (5th Edition)

☑ Review slides 8-11 of Character objects, cin, cout slides available in the Lecture Presentation Slides section of LTE.

☑ View the lecture on LTE in or format

Question 4 - I suggest you:

☐ Read in your textbook pages 57, 122-127 (4th Edition) or 52, 117-123 (5th Edition)

☑ Review slides 1-11 of Strings/Library functions slides available in the Lecture Presentation Slides section of LTE.

☐ View the lecture in either format available on the Built-In Data Types page in the Course Topic section of LTE.

Data type *string* and length(), find() and substr() functions
**Due to technical difficulties, only 80% of the slides are visible and /or

☑ Practise by doing the recommended exercises listed on LTE

Recommended exercises in textbook (page numbers in () are for 5th edition, others are for 4th edition)
Chapter 2: #9 p.90 (84) , #5 p.9 (85), #5 p.94 (87)
Chapter 3: #17 p.135(130), #7 p. 136(131)

Question 5- I suggest you:

☐ Read in your textbook pages 191-193,207-219 (4th Edition) or 184-185, 190-205 (5th Edition)

☑ Review slides 1-7, 13-16 and 19-23 of One-way/Two-way Selection slides available in the Lecture Presentation Slides section of LTE.

☑ View the lectures in either format available on the Selection page in the Course Topic section of LTE.

if/else
nested if

☑ Practise with the tool the functioning of the if /else and nested if statements available on the Selection page in the Course Topic section of LTE.

☑ Test your understanding by completing the on-line quiz for if /else and nested if statements available on the Selection page in the Course Topic section of LTE

☑ Practise by doing the recommended exercises listed on LTE

Recommended exercises in textbook (page numbers in () are for 5th edition, others are for 4th edition)
Chapter 2: #9 p.90 (84) , #5 p.9 (85), #5 p.94 (87)
Chapter 3: #17 p.135(130), #7 p. 136(131)

Question 6 - I suggest you:

☐ Read in your textbook pages 140-147 (4th Edition) or 136-143 (5th Edition) (Reading data)

☐ Read in your textbook pages 115-120 (4th Edition) or 108-114 (5th Edition) (Formatting data)

☐ Review slides 6-7 and 12-13 of Character objects, cin, cout slides available in the Lecture Presentation Slides section of LTE. (input)

☑ Review slides 15-17 of Character objects, cin, cout and 8-17 of Real Numbers, explicit/implicit type conversion slides available in the Lecture Presentation Slides section of LTE. (output)

☐ View the lectures in either format available on the Built-In Data Type page in the Course Topic section of LTE.
Character input from the keyboard
Floating-point numbers data types

☑ View the lectures in either format available on the Built-In Data Type page in the Course Topic section of LTE.
a first look at *setw()* manipulator for output
Floating-point numbers data types

☐ Practise by doing the recommended exercises listed on the Built-In Data Type page in the Course Topic section of LTE

Recommended exercises in textbook (page numbers in () are for 5th edition, others are for 4th edition)
#2 p.91 (85)

→ Feel free to come & see me if you need some help

Question 7- I suggest you:

- Make sure you understand difference between variable name & a string
- understand that a variable must be assigned a value before you print it.
- syntax of else as opposed to if

APPENDIX F - EXPLANATION FOR CHOICES OF LEARNING OBJECTS

The main goal of the digital LOs is to provide students with learning objects they could self-manage to assist them during the learning that occurs outside of class-time (bottom of iceberg in Figure 1 on page 16).

There are three categories of digital learning objects included in the LTE.

Lecture capture. The typical structure of my F2F lectures is as follows; I begin by introducing a concept, then model how to solve problems involving this concept, in other words the how and why and finally check for understanding by asking the students to try a few short problems on the spot. This classroom practise is a form of formative assessment which requires students to interact actively with the course concepts. It also informs me as well as my students on the next step. Are we ready to build on the current concept or do we need to revisit all or parts of it?

One of my teaching beliefs is that novice students benefit from direct instructional guidance when it comes to programming concepts rather than to be left on their own to discover them, a notion that Kirschner et al. reported on in 2006. From my 20 years plus of teaching, I have observed that novice students who are left to 'discover' approaches to solving computer programming problems are often frustrated with their progress (or lack of) and the quality of their learning.

The problem solving modelling, the second step in my teaching cycle is based on Bandura's Modeling Theory where an expert explicitly describes the rationale and methodology used while working through a problem (1977). In my position as an educator, I am the expert “scaffolder” meaning I am responsible for the learning of others (Holton & Clarke, 2006). As I am familiar with the material being presented, I am in a position to be able to offer both conceptual and heuristic scaffolding. The conceptual scaffolding is dealing with the specific computer programming concepts while the conceptual scaffolding is providing insight on which approach to take (Holton et al., 2006).

The lecture captures, which include both the animated annotations and audio, are recording both the conceptual and heuristic scaffolding occurring in the F2F environment and allowing students to revisit them as often or whenever they need to.

Formative evaluations. The second category of digital LOs involves formative evaluations which are to be used outside of class time. As discussed by Black and William (2009) formative assessment provides students the opportunity to be “owners of their own learning (p. 8).

My motivation is to facilitate students gaging where they are in their learning at any point in the term and to have the opportunity to take corrective measures where necessary prior to in-class summative assessments. Textbooks always include exercises that students can work with to evaluate their learning but often they don’t buy the textbook (which was the case in this study). Furthermore textbook exercises don’t always evaluate students’ learning the way I do in my summative evaluation. For those students who have access to the textbook, a list of recommended exercise is provided for each concept covered in class. The online exercises allow me to design assessments such that students can evaluate their acquisition of specific learning outcomes.

Interactive simulations. The final category of digital LOs is interactive simulation. As mentioned in the literature review, one of the challenges' students face when learning to program is to understand (visualize) the sequence of instructions being executed, how variables change and the output generated (Milne et al., 2002). One advantage self-scaffolding has over the expert "scaffolder" is "self- knowledge. Self-scaffolders know, to a large extent, what they know in terms of content knowledge [and] heuristic knowledge" (Holton, et al., 2006, p. 136).

The design of the applets is modeled on the drawings and sketches I use when explaining the flow of a computer program in class. The applets allow tudents to self-manage the use of the scaffolding options as they see fit during their session.