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How the Affordances Provided by a Technology-Enhanced Learning Intervention Can Impact the Self-Awareness and Self-Regulation of Students Taking a Community College Foundational Mathematics Course

Carol Barbara Carruthers
University of Windsor

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by

Carol Barbara Carruthers

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Carol Barbara Carruthers

APPROVED BY:

____
M. J. Hannafin, External Examiner
University of Georgia

____
W. L. Yee
Mathematics and Statistics, University of Windsor

____
F. Cherian
Faculty of Education, University of Windsor

____
T. DiPetta
Faculty of Education, Brock University

____
D. Martinovic, Advisor
Faculty of Education, University of Windsor

November 16, 2016

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ABSTRACT

Awareness of how one learns, and the ability to regulate one's learning for Ontario community college students taking a foundational mathematics course can be enhanced by a learning intervention which relies on the affordances of information and communication technology (ICT). An abundance of research was found on each these aspects independently, yet a deficiency in the literature exists that intertwines these facets. This non-sequential mixed-methods study utilized the affordances provided by an investigator-designed learning intervention. Seventeen students in a Mathematics Foundations for Technology (MFT) course participated in a learning intervention which consisted of surveys, the creation of studynote and screencast artefacts, scaffolded learning materials delivered via interactive software and pen-based tablet PC computing, and coursework maintained on the learning management system (LMS). Surveys gathered information regarding demographics, learning styles, attitude towards learning mathematics with technology, and ability to self-regulate. Students had the opportunity to experience and design artefacts, which were shared and tracked through the LMS. Reflective and active learners created studynote (a one-page document) and screencast (an audio and visual recording) artefacts, respectively. Six students participated in semi-structured interviews.

Little statistically significant data was obtained over the six-week intervention. Student comments illustrated that to create an artefact, they set goals and structured their environment, planned task strategies and managed their time. When artefacts were shared via the LMS, students evaluated and compared their product with others, and determined if further help should be sought. All of these elements contributed to a transformation in self-regulation skill. Findings were illustrated through a model which demonstrated how the wide scope of resources within a learning intervention, afforded through the use of ICT, can be streamlined to benefit students.

This narrowing requires students to be able to identify their learning preferences to guide their choice of resource. Recommendations for future research demonstrate that a greater understanding of how students prefer to learn, and can regulate their learning while using ICT, will afford a pathway for those who are hesitant or struggle in mathematics.

DEDICATION

My dissertation is dedicated to my parents, loving husband, three daughters and son, and to family, friends, supportive mentors and colleagues.

Your demonstration of patience and determination have guided me through this three year academic venture culminating in the achievement of a lifetime goal.

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CHAPTER ONE
INTRODUCTION

> “Perhaps one of the greatest challenges facing education is how we engage individuals with the learning process and design and tailor instructional methods to sustain positive changes that are feasible, accessible and realistic.” (Underwood & Farrington-Flint, 2015, p. 31).

Background and Rationale

Defining the Ontario community college system and its students

During the mid-1960’s it was recognized that a new educational stratum, the Ontario Community College system (Ontario Department of Education, 1967), was needed to meet the changing requirements of the workforce. To bridge the gap between (vocational) high school and university, colleges were designed to be occupation-oriented, specific to the local community and “encourage a learning atmosphere in which such students may feel reasonably comfortable-emotionally and socially: educationally and economically” (Ontario Department of Education, 1967, p. 33). Fifty years later the “Ontario colleges, with their mission of access, have become the higher education pathway choice for many students with a lower level of academic preparedness” (Dziwak, 2014, para. 2). With a greater number of returning-to-school adults, first-year students bring a wealth of past experiences and must negotiate their “sense of self and meaning based on these multiple realities” (Kasworm, 2003, p. 96). It is problematic that when placing students, registrars rarely pay attention to their socio-demographic traits and are missing information related to the students’ affective characteristics and personal factors (Boylan, 2009; Reason, 2009; Sedlacek, 2004). For some students, demographic factors (e.g., gender, age, ethnicity, parent’s education, and income) may be typical of placement into developmental courses (Reason, 2009). In addition, affective traits, like attitude toward learning, inclination to seek or accept help, willingness to expend effort, and desire to learn (Boylan, 2009; Garrett, 2010), may also be relevant. Educational researchers have noted that students in developmental courses often see themselves as weak in motivation, self-efficacy, attribution, and locus of control (Grimes & David, 1999; Wadsworth, Husman, Duggan, & Pennington, 2007). Failure perpetuates the cycle, as poor school performance is attributed to lack of ability, which in turn decreases motivation to learn, resulting in continued poor performance (Pressley & McCormick, 1995). Other external factors, such as working part-time or full-time, family situation, and need for childcare, may contribute to a perceived lack of ability (Boylan, 2009), difficulties in understanding and navigating the educational system, and/or limited access to teachers and other resources (Garrett, 2010). According to the Seneca College Strategic Mandate Agreement (2014) with the Ministry of Training, Colleges, and Universities (MTCU), future graduates will possess distinctive characteristics that are “highly attractive to employers” (p. 2). However, while community colleges enjoyed record enrollment in the 2013-14 year (Csanady, 2014), student demographics are changing. In Csanady’s report, enrolment data from 2013 indicated that only 33% of students arrived directly from high school, while the remainder were international or adults returning to formal education. According to Dziwak (2014), this shift in demographics requires institutions to provide increased remediation strategies as students arrive with “reading, writing and numeracy skills that are not considered sufficient for college-level work” (para. 5). Since both numeracy and literacy skills are critically important for the successful completion of college programs (Dion & Maldonado, 2013), the demographic factors should be closely monitored and pedagogy reviewed to align with changing student profiles (e.g., enhanced use of information and communication technology [ICT]).

The role of developmental mathematics

While a considerable amount of research demonstrates that student literacy falls below the level required for academic proficiency (e.g., Dion & Maldonado, 2013), of interest are the rather less studied aspects of Ontario student preparedness for taking college-level mathematics classes (Dion, 2014; Maciejewski, 2012; Orpwood & Brown, 2013). In line with the negative consequences of failing to complete a developmental mathematics course, it is essential to identify strategies that can potentially improve success of "at risk" college students (Hodara, 2011; Reason, 2009). Ley and Young (1998) summarized critical issues in this area by stating that, "research investigating underachievers suggests that developmental students may differ from regular admission students in the way they plan, organize, monitor, evaluate and even think about the learning process" (p. 47), indicating a lack of ability to self-regulate. Under-preparedness can be evidenced in poor engagement, absenteeism, and weak performance which are reflected in attrition and retention statistics (Fisher & Engemann, 2009).

Affordances of information and communication technology (ICT)

Many educational technology researchers use the term 'affordance' without providing its definition or theoretical background, which Brown, Stillman and Herbert (2004) found problematic. James J. Gibson (1979/2015) is credited for the term as the "*affordances* of the environment are what it *offers* the animal, or what it *provides* or *furnishes*, either for good or ill. The verb to *afford* is found in the dictionary, but the noun *affordance* is not. I have made it up" (p.127/119, emphasis in original). Donald Norman (1988) differentiated between real and perceived affordances, and explained the latter as "just how the thing could possibly be used" (p. 9). Norman's definition expands Gibson's as it relates more closely to the perceptions of the user and the usability of the environment (Brown et al., 2004). Kirchner (2002) applied this term to the student as their ability to learn within a given paradigm. Technological affordances align more closely to Norman's perceived affordance as they are an interaction of technological and social affordances (Kirschner, Strijbos, Kreihns, & Beers, 2004). From an educational perspective, Oliver (2013) theorized technology as an affordance and as a social endeavour. He suggested that there is a "significant gap" in the field of "educational technology" which revolved around the "failure to explain *technology* theoretically" (p. 31).

General statement of the problem

Students entering the first year of college diploma programs may not be equally ready or capable for performing at a post-secondary level (Dziwak, 2014). Research demonstrates that academically underprepared students may lack the ability to self-regulate (Ley & Young, 1998); they may be less motivated (Grimes & David, 1999) and may have poor study habits (Jairam & Kiewra, 2010). Those considered underprepared for the first year mathematics courses may be "at-risk" for successful completion of their chosen science or technology program (College Mathematics Project, 2007). To help these and other students to remain in the program and to be successful, educators look into the affordances for learning (Oliver, 2013) provided by the currently available ICT. These technology-enhanced learning opportunities allow students to communicate, explore, and analyze their mathematics thinking (Galbraith & Goos, 2003) with their instructors and peers.

Since 2007, students in technology programs at Seneca College are required to take a mathematics placement test (Canadian Achievement Test, CAT3-level 19) and, based on score, to enroll in a Mathematics Foundations for Technology (MFT) course. As MFT may represent a re-exposure to previously learned procedures and concepts, the use of the ICT was chosen to support learning, strengthen skills and improve success. Past offerings made the assumption that by simply providing multiple learning activities (Carruthers, 2010; 2012), students could determine for themselves how to best navigate a multimedia environment. A learning intervention in which college students taking developmental mathematics courses obtain skills in self-awareness and develop self-regulatory ability through the affordances of ICT would be informative for the Ontario post-secondary school system. For this study, the learning intervention consisted of surveys, creation of studynotes and screencasts, and using scaffolded learning materials delivered via DyKnow software and pen-based tablet PC computing, or through the learning management system (LMS).

Purpose of the Study

Current research into mathematics at Ontario community colleges is most commonly led and funded by government agencies, thus giving a high level overview of the system. Although this information is valuable, broad recommendations are difficult to implement. Without a focused vision containing specific direction and plans, the impact of this research to create sustainable change in the mathematics classroom is difficult to achieve. With decreasing scores in provincial and international mathematics testing, there is a demand on community colleges to reverse this trend by providing developmental mathematics courses. Research on how to specifically improve achievement at all levels is lacking, and this study looks to the learning potential gained by improving self-awareness and training self-regulation. As a subject matter, mathematics also requires the ability to draw on prior knowledge to build new concepts, thus, self-awareness and self-regulation are necessary skills for task completion. Further, for students enrolled in courses offered in hybrid mode (both face-to-face and online), the ability to autonomously regulate their learning is essential. The affordances provided by the use of ICT has not been measured for developmental mathematics students learning to self-regulate.

Research Questions

This study was designed to addresses the following three research questions:

1) How do the affordances provided by the learning intervention that are perceived to support metacognition (i.e., self-awareness and self-regulation) enhance self-regulation of students in a foundational mathematics college course?
2) How do student demographic factors (e.g., age, gender, and ethnicity) and attitude towards learning mathematics with technology relate to their utilization of the affordances of the learning intervention in a foundational mathematics course?
3) How does learning style, based on the active or reflective dimension, relate to student demographics, attitude toward mathematics, self-regulation, and choice of artefact in the learning intervention designed for students in foundational mathematics courses?

Theoretical Framework

Instructional design requires the researcher to have an understanding of the different learning theories, and for this study I have chosen constructivism. As one of my research goals is to "rely as much as possible on the participants' view of the situation being studied" (Creswell, 2003, p. 8), and as an instructor who prefers to build understanding with her students, the tenets of constructivism resonate most deeply with my practice. According to Noddings (2012), constructivist instructors "deemphasize lecturing and telling" (p. 127) and instead require students to be actively engaged in pursuing learning that meets with their expectations and objectives. My epistemological stance is one of social constructivism, as "not only is the environment transformed when adopting sociocultural practices, but so, too, is the pedagogical role of the teacher" (Bonk & Cunningham, 1998, p. 39). Constructivism acknowledges that an individual is able to gather information from their environment, build personal meaning, and thereby gain greater knowledge of the world in which they live and work (Phillips, 1995; 1997). In social constructivism, the teacher plays an advising role, and learners are active (Ally, 2004). Yet, Ally cautions that learners must be given time to internalize and reflect on the information they have derived so lasting connections can be made.

Dissertation Outline

This dissertation is comprised of five chapters. Chapter One describes the background that forms the basis of the study, and introduces the research questions. Relevant literature regarding learning in the digital era, including the affordances of ICT and the necessity of developmental mathematics, are explored through the perspective of learning styles and self-regulation in Chapter Two. With a deficiency of research surrounding community college students, the value of this study is evident. Chapter Three establishes a significance enhanced quantitative-dominant mixed-methods research design. Further it outlines research and data collection methods and analysis, and designates the learning intervention and the research timeline. The results are illustrated as tables and figures and supplemented with qualitative data from semi-structured interviews and activity surveys in Chapter Four. To conclude, Chapter Five discusses the findings from the study in the context of the literature and gives suggestions for future research, limitations, and practical applications.

Definition of Terms

Affordances: An affordance, as described by Norman (1988) "refers to the perceived and actual properties of the thing, primarily those fundamental properties that determine just how the thing could be used" (p. 9). In the context of this study, educational affordances are "the relationships between the properties of an educational intervention and the characteristics of the learners" and thus "once a learning need becomes salient, the educational affordances of a device or of a learning environment will not only invite but will also guide the member to make use of a learning intervention to satisfy that need" (Kirschner, Strijbox, Kreijns, Beers, 2004, p. 51). For this study in an educational setting, the affordances of the learning intervention were measured to determine student utilization, based on their perceptions, and their resultant actions.

Students at-risk: The College Mathematics Project (CMP, 2008) considered students at-risk as those in danger of not completing their college program. Mulvey (2009) used the term at-risk as "a label that implies a precarious position" (p. 29) and for higher education, noted it is also a label given to students who are under-prepared. For this study, students who are underprepared for college mathematics programs are considered at-risk.

Course delivery: Two modes of learning, blended and hybrid are "inconsistently defined in the literature creating a barrier to efficient research" (Margulieux, Bujak, McCracken, & Majerich, 2014). Using the Learning Experiences Taxonomy provided by Margulieux et al. for this study, the learning intervention was "practice hybrid [which] describes the combination between instructor- and technology-mediated experiences…the student applies knowledge with guidance and feedback partially via an instructor and partially via technology" (p. 6). As this taxonomy has not yet received wide acceptance, the literature review uses the following definitions: (a) a hybrid class which "have required amounts of physical attendance, but some of that attendance requirement is replaced by online work" and (b) blended where "classes meet face-to-face full time like regular classes but are augmented by formal, extensive online resources" (Johnson, 2012, p. 84).

Distributed learning: In distributed learning, resources are dispersed, educational interactions may be "initiated on a one to one, one to many, many to one, and many to many basis" (Locatis & Weisberg, 1997, p. 102). The learning management system (LMS) provides this affordance through various tools for communication, delivery and creation of content, administration, and assessment (Dabbagh & Kitsantas, 2005). For this study the LMS utilized Blackboard Learn.

Information and communication technology (ICT): Defining ICT is a challenge, as "diverse applications of the term ICT exist within several contexts and treatments" (Zuppo, 2012, p. 13). For this study, the term ICT represents the generalized use of computers/tablets or smart phones, the Internet, software, and courseware employed for learning.

Developmental mathematics: Three terms used to describe students who do poorly on mathematics placement tests are: foundational, developmental, and remedial. The term developmental, prevalent in U.S. based research, takes its origins from learning theory and developmental psychology, with a focus on the growth of the learner (Mulvey, 2009). For this work, developmental mathematics encompasses the literature where these three terms are used interchangeably (Bailey, 2009; Casazza, 1999; Dziwak, 2014; Maciejewski, 2012). Specific reference for students in the Mathematics Foundations for Technology (MFT) course uses the term foundational. The course was designed to be taken by students with weak scores on a post-admission placement test.

Numeracy: According to Dion (2014) numeracy requires the individual to demonstrate their use of basic mathematics skills in application to everyday situations (returning change, budgeting, measuring, pricing, calculating distances). This study uses the term mathematics to include numeracy as well as the skills required by outcomes determined by the Ministry of Training, Colleges and Universities.

CHAPTER TWO

LITERATURE REVIEW

In the past twenty years, the utilization of information and communication technology (ICT) has expanded into all areas of Ontario community college education and its use for the benefit of foundational mathematics students is gradually being noticed (Carruthers, 2015). The first section of this literature review considers specific characteristics of adult learners as they navigate the conventional and online courses available at the post-secondary level. To provide a context relevant for this research, the next section evaluates the literature on the importance of learning styles and provides support for a study of self-awareness and metacognition in learners, in particular related to the use of ICT. The chapter finishes with an in-depth examination of the literature related to an understanding of self-regulation, with a focus on adult learners using technology in developmental mathematics courses.

Learners in the Digital Era

In *Learning and the E-generation*, Underwood and Farrington-Flint (2015) caution educators to be aware that "the digital contexts in which individuals now learn have irrevocably changed" (p. 1). Unlike previous generations, learners today continuously utilize digital technology for various purposes; nevertheless, the authors argue in education its use "still remains controversial" (p. 3). This difference can be traced to the terms describing those who use or have access to digital technology (Brown & Czerniewicz, 2010). Futurists like Howe and Strauss (2000), Tapscott (1998, 2008), Prensky (2001a; 2001b) and Oblinger and Oblinger (2005) have argued that teaching methods must be adapted to meet the technological needs of students entering post-secondary institutions. Post-secondary students can identified as both traditional and non-traditional. Non-traditional student characteristics include "age 25 or older, have delayed entry into higher education after completing high school, did not earn a traditional high school diploma, are married, attend part time, work full time, or have children" (Eckel & King, 2004, p. 7). Many authors refer to this non-traditional group as simply adult learners (e.g., Wuebker, 2013). In contrast, traditional undergraduate students are younger, have come directly from high school, attend school full time, and work only part time (U.S. Department of Education, 2002). From a 2002 National Center for Education Statistics report by the U.S. Department of Education, 75% of all undergraduates had at least one non-traditional characteristic, while notably, the two-year public education institutions demonstrated the greatest concentration of students with four or more non-traditional characteristics.

Students born after 1980 have had the opportunity to become immersed in a technology rich world, and are thus classified by such terms as Digital Natives, Net Generation, and Millennials. Tapscott (1998) named them the Net Generation or N-Gen, and argued that although technology was relatively primitive, these children would be the first to grow up surrounded by digital media. These media could offer a student-centered education, tailored with constructive, experiential, non-sequential, and interactive learning experiences. Howe and Strauss (2000) classified Millennials as those born after 1982, who are captivated by new technologies and are "more numerous, more affluent, better educated, and more ethnically diverse" (p. 4). Prensky (2001a) designated the rapid increase in the use of digital technology as a "singularity" (p. 1), an event from which there would be no return as "students *think and process information fundamentally differently* from their predecessors" (p. 1). He coined the term Digital Natives to represent a younger generation with a natural affinity towards technology and whose "brains are almost certainly *physiologically different"* (Prensky, 2001b, p. 4). Digital Natives function best in a networked environment, where they are able to actively multitask rather than passively listen. Like Howe and Strauss, Oblinger (2003) considered the Millennial Generation as those born after 1982, whose "learning preferences tend toward teamwork, experiential activities, structure, and the use of technology" (p. 38). Although each of these terms were distinctly defined, most popular authors use them interchangeably or in combination to describe this generation of students who have grown up with technology at their fingertips (Jones & Shao, 2011; Underwood & Farrington-Flint, 2015).

Recent literature has argued that these widespread generalizations were too simplistic and "the time has come for a considered and disinterested examination of the assumptions underpinning claims about digital natives such that researchable issues can be identified and dispassionately investigated" (Bennett, Maton, & Kervin, 2008, p. 784). Papers by both Kennedy, Judd, Churchward, Gray, and Krause (2008) and Jones, Rammau, Cross, and Healing, (2010) have challenged the claim of a homogeneous generation while others provided a concise global representation of Digital Natives (Brown & Czerniewicz, 2010; Dahlstrom, Brooks, Grajek, & Reeves, 2015) and one drew comparisons across two generations (Joiner et al., 2013). To examine the assumption that Digital Natives entering a large metropolitan university in Australia had a "uniform digital upbringing" (p. 109), Kennedy et al. (2008) sought to gain empirical evidence of the entrenched (e.g., general computer skills) and emerging technology skills (e.g., social media) of first-year students. By completing a questionnaire, students were asked about their access, use, skills, and preferences for both well-established and newer technologies. The authors analyzed 1,973 of the total collected surveys, as they sought to only represent those born after 1980. Kennedy et al. learned that beyond the core skills required for the use of computers, phones, and email, a universal preference of other technologies was not apparent and that student choice of ICT was diverse. In fact, the authors cautioned that the mantra of "technological integration should be pedagogically driven" (p. 118) must be prefaced with a consideration of evidence based on equity (student access to technology) and diversity (student familiarity or preferences for technology). In a similar study, Jones et al. (2010) surveyed 596 first-year students who attended 14 different courses at five universities across England. Of interest, were the responses related to the frequency and nature of technology use in study and coursework by students born after 1983. Although students were actively using technology, Jones et al.'s findings did not indicate a homogeneous group, but rather a "complex picture of minorities" (p. 731). The authors concluded that students used technology with different proficiency levels, and a greater understanding of individual aptitude was required. Further, their study identified that students used "the same technologies for study purposes that they believed they were required to use on their courses" (p. 729). Over a six year study, Brown and Czerniewicz (2010) researched the use of technology by South African university students. Contrary to the characteristics used to define Digital Natives, their findings indicated that few had a similar skill level or access to technology. They concluded that the term digital will only be valued with a recognition of the "full array of literacies which students utilize and the affordances which they exploit" (p. 366). In 2015, the Educause Center for Analysis and Research (ECAR) sent a survey to almost one million undergraduate students at 161 institutions and received 50,274 responses from 11 countries (Dahlstrom et al., 2015). This yearly survey provides evidence-based information which enables researchers to observe patterns and predict technology trends deemed most important for postsecondary education. The 2015 focus was on students' use of mobile devices for anytime or anywhere connection and communication. From a selected group of 10,000 U.S. respondents, a key finding was that devices were apparent and although both students and instructors had a high interest in the use of mobile technology, actual utilization was “still not mainstream” (p. 11). Further, students may not demonstrate all of the attributes characterized as a Digital Native, yet their use of technology was both extensive and positive. In conclusion, Dahlstrom et al. commented that “leveraging technology as a tool to engage students in meaningful ways and to enhance learning is still more of a promise than a practice” (p. 4–5). Finally, in an Internet use comparison by first generation Digital Natives (surveyed in 2002) to that by second generation (surveyed in 2012), Joiner et al. (2013) matched the responses of 458 first-year psychology students. An Internet attitude survey was used to measure students’ frequency of use, anxiety, and perceived ability (Joiner et al., 2005; Joiner et al., 2012). Joiner et al. (2013) found that the frequency of Internet use and perceived ability was higher and anxiety lower for the second generation users. From an educational perspective, the finding that both only used the Internet for a few activities, primarily related to entertainment purposes, was of interest. This review of the literature establishes that not all generalizations of the Digital Native, Net Generation, or Millennial terminology have come to fruition in academic institutions. Nonetheless, this 20 year research focus has caused a greater interest in improved knowledge of the personal learning opportunities and supportive role of technology. Underwood and Farrington-Flint (2015) suggested that “the association between affordances of the technologies and learner-engagement is key to understanding what works, what does not and why” (p. 7).

Related to learning mathematics in an adult Canadian context, the Programme for the International Assessment of Adult Competencies conducted an international survey in 2012. Participants from 24 different countries ranging in age 16 to 65 years (a total of 157,000) were assessed on their skills and competencies. Canada scored below the Organization for Economic Co-operation and Development (OECD) average for numeracy (Statistics Canada, 2013). A U.S.

study of non-traditional students entering post-secondary institutions revealed unique characteristics that communicate a distinctiveness when related to the adult learning experience (Eckel & King, 2004; U.S. Department of Education, 2002). Such distinct learners require the learning environment to be modified to reflect their needs (Ausburn, 2004). With enhanced use of ICT, the learning landscape can be differentiated into multiple strata ranging from traditional face-to-face, to mixed modes including flipped, blended, or hybrid, to courses that are offered completely online. For diverse groups, Weubker (2013) advised that online learning reflects students' increased access to, and rise in personal use of ICT, and provides an alternative to the conventional classroom. Online learning appeals to adult learners engaged in professional upgrading, as it facilitates choice, uses a wider range of resources, is more flexible for busy lifestyles, supports self-directed approaches, and is a transferable skill for the workforce (Mason, 2006). To increase the chance for success and program completion by adult students, a consideration of the online environment requires that both the strengths and weaknesses of digital forms of learning are examined (Oblinger, 2003). Questions of who is using ICT and for what purpose, and even more importantly, who is not using ICT and why, remain largely unanswered to the extent that "mapping how ICTs and the ICT-based learning fit with the everyday lives of adults is a vital task for the research community" (Selwyn, Gorard, & Furlong, 2006, p. 1). Wuebker (2013) recommended that the design of an online course must account for the individual learning styles of the adult learner, in addition to promoting the development of a community of learners and their ICT skills. Rakap (2010) postulated that "students knowledge gain changes as a function of learning styles" (p. 113) and advised that online instructors need to pay a greater attention to the learning styles of their students. Hawk and Shah (2007) reviewed the benefits and limitations of six learning style instruments. The authors proposed that these instruments should be regarded as diagnostic tools "to inform the choice of learning activities" (p. 14), and that instructors have a responsibility to develop experiences which address a spectrum of learning styles. In addition, they proposed that students should be made cognizant of class (anonymous) and instructor learning profiles, to develop a consciousness of how learning occurs. With this awareness, instructors can demonstrate processes that match various needs, thereby individualizing learning as well as providing the opportunity for students to explore modes that may not be a usual or familiar practice. To maximize learning opportunities, many researchers agree that learning styles should be identified and online teaching approaches modified to meet the specific learning needs of students (Drennan, Kennedy, & Pisarki, 2005; Hawk & Shah, 2007; Rakap, 2010).

As reviewed above, benefiting from the affordances provided by the enhanced use of ICT, it is possible to create an environment where both traditional and non-traditional adult students can learn. The question is then, is this practice occurring within the Ontario College System? In 2011, the Higher Education Quality Council of Ontario (HEQCO) called for research projects aimed at gathering a greater perception of how technology is used and incorporated into instruction for post-secondary students. To summarize findings and to forecast emerging trends, HEQCO provided an @ Issue Paper in which Lopes and Dion (2015) synthesized the research of the contracts awarded for the 2011 call. Of the nine papers reviewed, seven related to implementation of technology in university courses. Ghilic, Cadieux, Kim, and Shore (2014) assessed the use of audience response systems (iclickers) with over 3,000 McMaster first-year introductory psychology students; Reid et al. (2014) used digital planetariums for 852 University of Toronto first-year astronomy students; at Queen's University, Leger et al. (2013) compared the learning boundaries of a blended course design with over 600 students in a first year human geography course; Samuels, McDonald, and Misser (2013) studied the use of an online assignment planner to enhance the writing skills of first year students attending Wilfrid Laurier University; at the University of Waterloo, Pretti, Noël, and Walker (2014) looked at an online programme to develop the essential employability skills for over 24,000 co-operative education students; Martini and Clare (2014) asked 141 third- and fourth-year psychology students at Brock University to use e-portfolios to measure gain in transferable skills; and at the University of Toronto, Paré, Collimore, Joordens, Rolheiser, Brym, and Gini-Newman (2015) used software to help students develop a sense of community in a first year introductory psychology course that, dependent on student choice, was either fully face-to-face, fully online, or any mixture thereof. Only two Ontario community college results were reviewed in the Lopes and Dion (2015) report. Waldman and Smith (2013) sought to "fill this gap in the literature" (p. 5) and compared 49 Sheridan College face-to-face courses to those taught in hybrid mode by the same instructor the following semester. At Lambton College, Elliott and Colquhoun (2013) studied the impact of learning studios on factors of student achievement, success and satisfaction, from 11 courses taught in an active classroom. It was "designed to support teaching and learning in an atmosphere conducive to engaging students actively in their own learning" (p. 7). A general finding from this study was that students appreciated the space and adopted several of the active learning strategies, but found the use of technologies inadequately realized due to a lack of instructor training. Although the work presented here is neither about the benefits of teaching in hybrid mode or in an active classroom, this @ Issue Paper by Lopes and Dion (2015) gave an indication of the paucity of academic research occurring within the Ontario Community College system. Thus, it can be concluded that there is a gap in the research describing the innovative and effective use and implementation of ICT for both traditional and non-traditional community college students.

The importance of community college developmental courses. Numeracy and literacy are defined as essential skills by both the Canadian Federal and Ontario government agencies (Dion, 2014). The PIAAC Numeracy Expert Group (2009) defined numeracy as “the ability to access, use, interpret and communicate mathematical information and ideas, in order to engage in and manage the mathematical demands of a range of situations in adult life” (p. 21). Due to the breadth of information available related to universities, colleges, and apprenticeship programs this section includes only research specific to community college mathematics. The King Report (King, Warren, King, Brook, & Kocher, 2009) analyzed data obtained from the Ontario Colleges Application Service (OCAS) and the Ontario Universities’ Application Center (OUAC) for the 2001-2002 to 2006-2007 academic years. The data were used to determine graduation status as well as post-secondary destination choices of college applicants. With a focus on students who potentially enter colleges, important information can be obtained from the 2002-2003 Grade 9 cohort results. Of the 67% of the Grade 9 students who took academic mathematics, 87% completed Grade 12 and received their Ontario Secondary School Diploma (OSSD), whereas, of the 28% who took applied mathematics, only 58% of those obtained their OSSD. As taking applied courses indicates a direction towards college, this finding by the King Report suggested that almost 40% of applied mathematics students will not attend college directly from high school. With this time gap between high school and post-secondary education, students in the applied stream are more likely to need upgrading programs (King et al., 2009). From 2007 to 2015, the multi-institutional Ontario team, the College Student Achievement Project (CSAP – formerly the College Mathematics Project [CMP]) analyzed the mathematics accomplishment of first semester college students based on their secondary school achievement (CSAP, 2015). The Project found that at least one-third of students in the technology cluster may not complete their chosen program (CMP, 2007). In an @ Issue Paper prepared for HEQCO, Dion (2014) emphasized the lack of numeracy skills among college students, and called for changes to both mathematics curriculum and its delivery. In conclusion, the existing research tackling developmental mathematics courses demands a greater understanding of the learning needs of all students.

From an international perspective, a significant amount of literature addresses community college programs in the United States. With the open access and affordable options offered, students have increasingly turned to community colleges as a "doorway to attaining their academic goals" (Bol, Campbell, Perez, & Yen, 2016, p.481). In a longitudinal study of 107 California community colleges, Peter Bahr (2008) found that students who successfully completed remediation "exhibit long term academic attainment" (p. 446). Unfortunately, Bahr also noted that the majority of students did not remediate successfully. Although the U.S. programs are dissimilar to the Ontario post-secondary educational structure, they provide valuable guidelines as they search for ways to increase student retention (Bahr, 2013; Fike & Fike, 2008), deliver effective mathematics instruction (Hodara, 2013), and provide learning assistance (Perin, 2004) for students taking developmental mathematics courses. In a four-year quantitative study designed to determine predictors of student retention, Fike and Fike (2008) collected data from 9,200 students at an urban Texas community college. Based on regression models, the authors found that the successful completion of a developmental reading course was the greatest predictor of student retention. An unexpected finding was that the likelihood of retention was stronger for students who took a developmental mathematics course, regardless of completion. This study indicated that taking developmental courses, including mathematics, contributed favourably to the success of community college students. In a Center for Analysis of Postsecondary Education and Employment (CAPSEE) working paper, Hodara (2013) provided an extensive literature review. While most of the studies investigated effects of early assessment, cost-effective strategies, and the possibilities of computer instruction and moderation, of interest was a requirement for effective mathematics instruction as a direction for future research. Hodara found that much of the current offerings in developmental mathematics instruction relied on procedural skill-building, traditional mathematics instruction, or remediation pedagogy. Although such curricula may result in better performance on standardized testing, Hodara recommended that future research must look at the "adoption and adaption of effective math instructional strategies" (2013, p. 39). In a large qualitative study by Perin (2004), the goal of the research was to understand the ways that learning assistance centers can help to increase academic preparedness of adult learners. After analyzing 458 interviews gathered from 15 sites across six states, Perin found that mathematics remediation courses took on several different forms. The examples ranged from offering mathematics laboratories to study groups organized in centers staffed with continuously available tutors. Perin noted that self-paced remediation courses enriched with computer assisted instruction were highly popular among adult students, although no details were given as to the specific delivery of materials in relation to their benefit.

In summary, a review of research studies regarding weak numeracy/mathematical skills gives credence to the need for developmental mathematics courses at the post-secondary level. An understanding of student academic and affective specifics gives a clear picture of the necessity for courses that are innovative and designed to provide new learning opportunities to students who may otherwise struggle and become disengaged. Most authors (e.g., Hodara, 2011,

2013) conclude that further research is required to gain a greater cognizance of how to assist individual adult students.

Learning Styles to Develop Metacognitive Awareness

As previously mentioned, non-traditional students have differing learning requirements (Eckel & King, 2004), thus an instructional design which places a greater focus on individual learning styles (Rakap, 2010) can be addressed with an enhanced use of ICT (Weubker, 2013). Because the unified terminology is missing, those interested in student learning styles must find a definition that closely resonates with their research interests. A original characterization offered by the National Association of Secondary School Principals (NASSP) Learning Styles Task force defined learning styles as “characteristic cognitive, affective, and physiological behaviours that serve as relatively stable indicators of how learners perceive, interact with, and respond to the learning environment” (Keefe, 1979, p. 4).

Theorists in multiple disciplines have studied learning styles from different perspectives. In their review of research regarding learning styles specific to the post-age 16 demographic, Coffield, Moseley, Hall, and Ecclestone (2004) found it “characterised by a very large number of small-scale applications of particular models to small samples of students in specific contexts” (p. 1). The authors described learning styles as a “complex research field” (p. 1), which although disjointed, could broadly be categorized into three areas: (a) theoretical exploration, (b) pedagogical development, and (c) commercial application. A theoretical exploration of 71 different models caused the authors to classify only 13 models as major, based on determined criteria. Related to pedagogy, Coffield et al. commented on the diversity found between models drawn from various disciplines (i.e., psychology, sociology, education, and policy studies). Since each discipline acknowledged or refuted findings based on their respective stances, the authors suggested that the field was fraught with “fragmentation, with little cumulative knowledge and cooperative research” (p. 1). With respect to commercial promotion of learning style instruments (e.g., guidebooks for teachers, questionnaires for purchase, and professional development workshops), Coffield et al. questioned the strength of the empirical research on which these instruments are based. In general, Coffield et al. established that it was the wording of test items, scoring methods based on subjective judgment, and instrument reliability, validity and commercialization that fueled an oppositional stand to learning style measurement. Although this review is considered a cornerstone in the literature, it must be remembered that the authors’ stance was one in which teaching, learning, and assessment were considered as “one interactive system” (p. 119). No attempt was made to assess students and teacher strategies separately, nor to distinguish the actual student learning from what was being measured by assessment. Finally, and perhaps due to the timing of this review, Coffield et al. did not consider the impact that ICT may have on learning styles.

With the “complexity and controversy” (Coffield et al., 2004, p. 1) surrounding this phenomena, coming up with a simple definition of learning style can be challenging. Sternberg, Grigorenko, and Zhang (2008) defined learning styles as “individual differences in approaches to tasks” that determined the way “a person perceives, learns, or thinks” (p. 486). They theorized that learning styles could be regarded from two perspectives—ability-based and personality-based. Ability-based styles referred to the integration of creative, analytical, and practical thinking capacities required for “successful intelligence” (p. 487). Of greater interest, personality-based styles related to the autonomy of the learner to use their specific skill set in certain ways. Sternberg et al. listed the general characteristics of personality-based styles and drew the following conclusions: a) they depended not on whether the learner had the capacity to accomplish the work (ability-based), but rather on the preference for the work; b) they were measured as the strength of the match between the learner, the instructor, and the material, noting that "environments almost invariably tend to favor certain personality-based styles over others" (p. 499); c) they were flexible, modifiable and varied both within and across tasks; and d) they were not static in that learning can be social and changed depending on the situation. Pashler, McDaniel, Rohrer, and Bjork (2008) also made the distinction between learning styles as a "specific aptitude" (p. 109) versus preferences. Specific aptitudes related to the individual's mental ability to process information, whereas preferences related to their preferred mode of instruction. The authors found that these distinctions were often "very closely intertwined in many discussions of learning styles" (p.109). In addition, Pashler et al. commented that the "meshing hypothesis" (p.109)—a view that certain instructional modes favour particular learning styles, resulted from this lack of distinction. They defined a "learning style hypothesis" as the "claim that individualizing instruction to the learner's style can allow people to achieve a better learning outcome" (p.108). From their survey of the literature, Pashler et al. developed the following experimental criteria in order to prove the relevance of learning styles. Participants must: 1) have their learning style assessed, 2) be randomly grouped and treated with opposing learning approaches, 3) be given a common evaluation of academic success, and 4) demonstrate improved performance based on only one learning approach. Based on these criteria, Pashler et al. did not find support for the learning style hypothesis. They postulated that educators might be attracted to the idea of learning styles, in the belief that some students can benefit from certain interventions more readily than others, but they did not recommend that the added cost of implementing a learning style model could be warranted. They cautioned that teaching techniques should be upgraded based on evidence that has experimental foundation, not based on widely held popular beliefs, like that learning styles exist. They concluded that educational research should focus on experiences and challenges that are known to provide learning improvement. In 2012, Rohrer and Pashler reiterated this argument, and added that to supply the multiple course options for the benefit of all learning styles would be "logistically demanding" (p. 636). Taking this criticism further, Kirschner and van Merriënboer (2013) stated that designing instruction based on learning styles contributed to an "urban legend in education" (p. 169). They discussed three fundamental problems related to the notion of "putting learners into pigeonholes" (p. 173): poor fit for some individuals, use of self-reported measures, and the impracticality related to the number of potential variations. They submitted that students may be unable or perhaps unwilling to share their learning preferences in the form of the multiple choice response surveys. Irrespective of the difficulties in the measurement of learning styles, Kirschner and van Merriënboer supported Pashler et al.'s concern of the meshing hypothesis with a reckoning that accommodating for student preference may not lead to productive learning. Willingham, Hughes, and Dobolyi (2015) acknowledged that the attraction of the learning styles theory was an alternative to an educational practice that treats all students the same. They agreed with Pashler et al. (2008) that viable research on learning styles must follow strict guidelines. Their objections to learning styles research were stated clearly with comments such as: "theories have not panned out" (p. 269), they "ought to be debunked" (p. 268) and "it is our responsibility to ensure students know that" (p. 269).

A review of the literature finds the controversy regarding learning styles still being argued by academics and researchers as well as a contention in social media (e.g., Oxenham, 2015). In designing pedagogy, instructors must consider how material is presented to make it easily understandable and memorable for all students. With the vast array of theories regarding learning styles, a researcher must choose the one most resonant for their students. One rationale for making this choice is to use an instrument that was developed specifically to enhance learning for adult science students. Concerned with poor student attendance, participation, and grades in first-year university engineering courses, Felder and Silverman (1988) sought a concrete solution. From their individual backgrounds of educational psychology and engineering education, they combined their knowledge to develop the Felder-Silverman Learning Style Model (FSLSM), based on the premise that learning is “a two-step process involving the reception and processing of information” (p. 674). Felder (2010) has noted that it is important “to maintain a realistic perspective of this unfortunately controversial subject” (p. 5). He found that “most learning styles debunkers base their arguments on the meshing hypothesis” (p. 3) and agreed that it would be impossible for educators to change pedagogy based on individual students’ style. However, Felder countered with the recommendation that learning styles were nothing more than effective pedagogy, obtainable by an instructor reviewing the applicable literature. The FSLSM was constructed based on responses to the following questions:

1. What type of information does the student preferentially perceive? [sensory or intuitive]
2. Through which sensory channel is external information most effectively perceived? [visual or auditory]
3. With which organization of information is the student most comfortable? [inductive or deductive]
4. How does the student prefer to process information? [actively or reflectively]
5. How does the student progress toward understanding? [sequentially or globally]

(Felder & Silverman, 1988, p. 675)

Recognizing the breadth of individual styles, Felder and Silverman chose only certain dichotomous opposing dimensions to develop their model as an entity to collectively provide a good basis for effective instruction (Felder, 1993). They publically admitted that their model was a synthesis of known theories of the time (Felder & Silverman, 1988). For example, the active or reflective scale was similar to the Kolb model (1984) and based on the introvert-extrovert theory of Jung-Myers-Briggs (Lawrence, 1987). Felder and Silverman (1988) listed simple modifications for post-secondary instructors to supplement their pedagogy based on learning styles. For example, the authors suggested that lecturers employ moments of brainstorming for active learners or short thinking breaks for reflective learners to give a balanced teaching approach. With time, some modifications have been made to the original FSLSM questionnaire. In an updated version of this paper published in 2002, Felder's preface described changes made by replacing auditory with verbal and the removal of the inductive or deductive dimension. In 1991, Richard Felder and Barbara Soloman developed the Index of Learning Styles (ILS) instrument. This instrument originally contained 28 items, but after it was subjected to analysis and revised, it presently contains 44 items. In 1997, it was released to the public as a web version, allowing individuals to determine their own learning styles at no cost (Felder & Brent, 2005). Using the ILS instrument (Felder & Soloman, n.d.) both student and instructor can assess not only their learning preference, but also the extent to which it prevails based on a three-point scale (i.e., mild, moderate, and strong).

Although controversy surrounds the conceptualization of learning styles, if the goal of the instruction is to increase "metacognitive awareness" (p. 4), Felder (2010) recommended that students should assess and discuss their preferred learning styles, allowing them to benefit "from learning about how they learn" (p. 1). From their extensive literature review, Coffield et al.

(2004) concluded that, “a knowledge of learning styles can be used to increase the self-awareness of students” (p. 119). Learners who are encouraged to become more self-aware develop a greater understanding of their strengths and weaknesses. Felder (2010) maintained that if students know about learning styles and were aware of how the process works, they may be less critical of themselves as learners and more willing to demonstrate their unique abilities, resulting in a more positive attitude towards education. In addition, not only would students know about their own learning, but they would also recognize qualities possessed by other learners. According to Coffield et al. (2004), for learners, “such knowledge is likely to improve their self-confidence” and to “give them more control over their learning” (p. 119). By having this awareness, Sadler-Smith (2001) offered that students will monitor and perhaps question their long-held learning behaviours, to determine personal effectiveness. Sadler-Smith (2000) found that “an effective learner” (p.197) can autonomously recognize the weaknesses in their preferred learning strategy, and opt for a more appropriate one. To acquire this level of effectiveness, it is necessary to first make students aware of their learning preferences. Instead of waiting for students to make such discovery on their own through trial and error, Coffield et al. (2004) suggested using learning styles as an “activity-based introduction to the topic of learning” (p. 120). Torres (2014) shared the results from a learning style instrument with 229 New York City community college students of Latino origin, to encourage them to develop their own effective learning strategies. She recommended that by having a greater knowledge of how students prefer to learn, teachers can take different pedagogical approaches to provide more effective support. De Vita (2001) described students enrolled in a graduate level international business management course in the United Kingdom, as a “culturally heterogeneous groups of learners” (p. 172). For teachers, knowledge of the differing learning styles present in this group allowed for the development of inclusive instruction. Using the ILS survey (Felder & Soloman, n.d.) the author found international students had a broader spectrum of learning style preferences compared to home (British) students. De Vita concluded that any frustration and dissatisfaction found in international students could be reduced by providing an environment suitable for students with different learning styles. For those less confident about their learning, a discussion of styles can offer the required vocabulary necessary for further self-exploration. This much needed "lexicon of learning" (Coffield et al., 2004, p. 120) can deliver an opening for discussion of preferences and strategies which can be further enhanced to explain methodologies to develop self-regulation.

Learning styles and ICT environments. As previously described, many learning style models exist, each with their predictive surveys. To narrow the scope, only research regarding the use of the FSLSM will be reviewed. The use of ICT can provide differentiated environments for students to choose how they will learn based on personal preferences. A model described by Caverly, Peterson, Delaney, and Starks-Martin (2009) outlined the changing roles of technology from one as a "tutor" to one as a "support tool." As a tutor, technology is a vehicle for a one-way transfer of knowledge from the expert teacher/machine to the novice student, thereby delivering information to improve skill level. When employing technology as a support tool, the student role changes from a passive receiver to an active seeker of information. Although the ILS (Felder & Soloman, n.d.) measures learning styles in four dimensions, considering ICT in a support role, this review will focus on results pertaining to the active or reflective dimension.

In efforts to determine the impact of learning style, researchers have experimented with enhancing online course design (Moallem, 2007), altering the conventional use of discussion boards (Battalio, 2009; Jeong & Lee, 2008), and the type of environment used for community-based learning (Zhan, Xu, & Ye, 2011). After an extensive literature review, Moallem (2007) developed a list of six assumptions common to all learning styles, and used them to guide her selection of the Felder-Silverman Dimensions of Learning Style model (FSLSM: Felder & Silverman, 1988). In designing teaching materials based on the FSLSM for an online graduate level course, Moallem considered three suppositions: (a) learners can become more self-aware by knowing their learning style, (b) choice from all dimensions should be available, and (c) participants should choose how they prefer to learn, but should also be challenged to try other methods. Fourteen students aged 26 to 60 years participated in an instructional design theory course. Two units of the course were taught traditionally, and two (experimental) units were redesigned to incorporate the three previously mentioned suppositions. Learning styles were measured using the ILS. From analysis of the course analytics, Moallem found differences in students' use of online resources based on their learning styles. For example, reflective learners spent more time reviewing content materials in the experimental units than active learners. Jeong and Lee (2008) observed that although discussion boards are commonly used in online courses for sharing ideas and information, there was a scarcity of studies exploring argumentative discourse. For 33 graduate students enrolled in a distance education course at a southeastern U.S. university, the authors sought to develop "computer-supported critical argumentation (CSCA)" (p. 652). Eleven of the 44-items from the ILS questionnaire, specific for the active or reflective dimension, were used to measure students' learning styles. Discussions from the learning management system (LMS) were analyzed and coded for frequency of responses which indicated certain argumentation characteristics. Although active and reflective learners posted the same number of comments, Jeong and Lee observed that those given by reflective learners received more critical discourse responses from both active and reflective learners alike than those by active learners. The authors concluded that learning styles can impact the quality of discussions. In a study of 120 students taking an online English Technical Communications course at a Midwestern U.S. university, Battalio (2009) compared participant responses to LMS usage in two formats: (a) a collaborative version and (b) a self-directed version. Participants completed several types of surveys (demographic, ICT usage, satisfaction), as well as the ILS instrument. Battalio found that reflective learners were more successful than any of the other ILS learning dimensions for both formats of the online course. When compared to active learners, reflective learners had significantly higher grades, learning management software use, and online interaction. Reflective learners preferred to work on their own, but they also had more interactions in the collaborative version of the course than did the active learners. Battalio concluded that reflective learners appear to be the "greatest beneficiary of the online environment" (p. 83). Zhan, Xu, and Ye (2011) compared the impact of an online learning community (OLC) on the performance of students identified with active and reflective learning styles. The authors believed that an OLC provided "a better collaborative environment for communication as well as knowledge and resources sharing" (p. 961). In total, 814 first-year students were randomly assigned to a digital design course offered in two different modes: one offered an OLC, and the other did not (NC). Learning styles were measured using the ILS, and students were assigned to heterogeneous groups. The findings demonstrated that both active and reflective learners performed significantly better in the OLC course, based on pre- and post-testing. Zhan et al. established that active learners performed better in face-to-face environments, while reflective learners performed better in online environments. The authors concluded that an OLC should be offered as a choice, and that learning style preferences should be considered in instruction design. As described, student participation in an online environment may be impacted by learning style, and in particular by whether students are active or reflective learners. In contrast, Dabbagh (2007) suggested that with the use of web-based environments that are interactive and collaborative, multimodal (e.g., use audio, video and text modes), and provide both linear and non-linear formats, there may be less need to "cater to a variety of individual learning styles" (para. 5) for student success.

It is important to know if learning styles influence how students are making use of the provided resources (Huang, Lin, & Huang, 2012) and students' level of engagement with them (Cheng & Chau, 2016). Huang et al. hypothesized that learning style is a predictor of e-learning performance, yet little is known of the "mediating and moderating effects between the two" (2012, p. 338). These authors studied 224 college students in Asia taking an unspecified online course in the Information Sciences Department. Participation was tracked by the "students' online trail" (p. 343) and recorded as active (making postings on discussion boards and viewing files) and passive (length of time viewing non-interactive pages and number of page views). Learning styles were assessed using the ILS (Felder & Soloman, n.d.) and their results demonstrated that online participation is a mediating construct between students' learning style and e-learning performance. In a blended learning course, Cheng and Chau (2016) explored the relationship between students' learning styles, their participation, learning performance and satisfaction. While enrolled in a general education Digital Citizenship course, 78 students completed the ILS survey. Students worked individually on a materials development activity and created their own digital artefacts, which researchers quantified. Like Huang et al., Cheng and Chau explored relationships between the various constructs and found that the quality of online participation was associated with learning styles. In addition, the average frequency of participation of reflective learners in the materials development activity (reflective journals and presentation files) was significantly higher than any of the other learning style categories. The researchers showed that participation in the materials development activity "required students to think critically and then to showcase what they learned" (p. 274). Although not specifically related to learning mathematics, current learning style research investigates how students interact and engage with ICT.

In an online environment, based on research findings of the impact of learning styles, it is apparent that students interact with course materials in unique ways. In an effort to specifically examine how technology enhanced learning systems can provide a more relevant learning experience for students from Austria and New Zealand, Graf, Viola, Leo, and Kinshuk (2007), determined representative characteristics of learning styles. Each of the 44 items of the ILS instrument (Felder & Soloman, n.d.) were semantically analyzed and grouped. For example, the 11 items used to describe an active or reflective learning style were individually categorized as 'trying something out' versus being 'socially oriented,' (active) and 'think about material' versus being 'impersonally oriented' (reflective). Of the 207 students studied, for those with an active learning style, "the preference for trying something out has more impact than the preference for social orientation", while for those with a reflective learning style "the social behaviour is more relevant than the preference to think/reflect about learning material" (p. 86). These outcomes give depth to characteristics that define the active and reflective dimension, and thus, a greater discernment into learning preferences of students. Additional applications of this research included development of LMSs to automatically detect learning styles (Graf, Kinshuk, & Liu, 2008) and cognitive traits to enhance performance in online courses (Graf, Lin, & Kinshuk, 2008; Graf, Liu, Kinshuk, Chen, & Yang, 2009). Extending their previous research, Graf, Liu, and Kinshuk (2010) acknowledged that LMSs have much to offer post-secondary instructors;

though little is known as to how students are actually using the provided resources. Since the authors contend that "individual differences affect the learning process" (p. 117), Graf et al. (2010) compared the learning styles and navigational behaviour of 75 Austrian computer science students taking an information systems course. Participants completed the ILS and registered into the online course enhanced with multiple activities, learning objects and resources. To aid in determining student navigational behaviour, each section of the course had an overview page which outlined all available activities and resources. The tracking mechanism of the courseware allowed Graf et al. to analyze in which order and for how long the students used the resources. For active learners, a common path was to go to the overview page, to the discussion forum and back to the overview page, a pathway that was not significant for reflective learners. The authors concluded that active learners went more often to the forum page, but only read a few posts, whereas reflective learners went less often, but once there, read several posts. Active learners also tended to jump from content areas to conclusions and re-submit exercises more frequently than did reflective learners. Further, reflective learners worked more in the self-assessment and feedback areas of the course, which was not seen in active learners. Although this literature review considered demonstration of results for only the active or reflective dimension, similar findings for other dimensions allowed Graf et al. to confirm that the students' navigational behaviour within the LMS was dependent on their learning styles.

Current work in the learning style field relates to the use of adaptive computer systems for assessment (Truong, 2016) and design of social media based on styles (Balakrishnan & Gan, 2016). Truong (2016) reviewed 51 studies to determine the extent to which learning styles were used in the integration of adaptive systems. The Felder-Silverman model was credited as being "by far the most popular theory applied in adaptive learning system" (p. 1189). The author recommended the use of data mining and computer learning algorithms to track student behavior throughout the course, as opposed to the previous practice of asking students to complete a questionnaire, which is based on a perception and evaluation at only a single point in time. In their recent work, Balakrishnan and Gan (2016) researched a topic that was missed in the literature—the intention by students to use social media for learning based on their learning styles. After providing an overview of the various types of social media, the authors chose Facebook, Twitter, wikis, and YouTube for their study. The authors concluded that activities designed for learning using social media, "should be inclusive of diverse learning styles" (p. 819).

Teaching students in post-secondary education requires instructors to have the knowledge required to deliver the curriculum and the comprehension of student ability to invoke engagement. Battalio (2009) suggested that online learning "by its nature privileges those who are self-directed, independent, and goal-oriented" (p. 74). A review of the literature finds that individual learning style, such as whether the learner is active or reflective, can influence student online interaction and resource choice. As "students enrolled in developmental courses have encountered the information previously and have not retained it" (Wadsworth, Husman, Duggan, & Pennington, 2007, p. 6 – 7), developmental mathematics teachers are confronted with many challenges (e.g., see the section on non-traditional learners). To respond to these challenges and to accommodate diverse populations of students, instructors can employ pedagogy and resources that incorporate the theory of learning styles.

Learning styles and learning mathematics with ICT. To address the concern around low completion rates in developmental mathematics courses, coupled with the lack of persistence in further mathematics courses in U.S. colleges, Hodara (2011) reviewed literature that related only to reformative classroom pedagogy. The focus of this CAPSEE study was to "identify promising developmental math pedagogy" (p. 3). Upon review, Hodara found few empirical studies of relevance to this population, so expanded the scope to include K-12 and all college levels of mathematics with the understanding that existing pedagogy could be adapted for adult students. Each paper was classified based on the primary instructional approach resulting in six categories. The greatest number of papers that related to pedagogy for teaching developmental mathematics utilized computer-based learning. A broad categorization of studies included: a) textbook support (McClendon & McArdle, 2002; Speckler, 2008; Taylor, 2008), b) course redesign (Squires, Faulkner, & Hite, 2009; Twigg, 2005), and c) lecture preferred instruction (Waycaster, 2001; Zhu & Polianskaia, 2007). There was only one paper reviewed that was specific for learning style (Garcia, 2003) and one that studied differentiated instruction with learning style as a parameter (Zavarella & Ignash, 2009). Of relevance, the underlying theory for computer-based learning depended on the premise "that students are active in the construction of knowledge" (Hodara, 2011, p. 21). To develop pedagogy that allows students to actively construct knowledge "educators need to spend time understanding learner's current perspectives and, based on this information, incorporate learning activities that have real world relevance for each learner" (Kanuka & Anderson, 1999, para. 6).

Inspired by Hodara's study, a brief review of the literature as it relates to K-12 mathematics students will be undertaken, with a perspective that findings can be applied to adult students. As Malaysian students are increasingly turning to the individualized mathematics instruction at tuition centers, Zin (2009) suggested the use of interactive instructional software (A-MathS). To counter the idea that all students have the same abilities, this multimodal courseware was designed and developed to match students' learning styles. This learning style model was defined based on "cognitive style and modality preference" (p. 1511), and the results indicated that mathematics students can benefit when the teaching approach incorporates learner preferences. For Turkish high school students, computer use and application is widespread for teaching mathematics courses (Özgen & Bindak, 2013). As the materials designed for computer use are based on a constructivist learning approach, Özgen and Bindak advised that instructors should use learning styles to gain a greater insight into student preferences. The purpose of their research was to examine this relationship, as "no studies can be found regarding students' opinions on computer use in mathematics education based on learning styles" (p. 81). Using the Kolb learning style model (Kolb & Kolb, 2005), the researchers concluded that in course design and delivery, learning styles and student opinion should be considered. Aral and Cataltelpe (2012) reviewed the literature to better understand focus on how learning styles can enhance performance in mathematics for students in K-12. Their review found that most commonly questionnaires, rather than automated systems, were used to monitor and track student learning style in an online system. Aral and Cataltelpe drew the conclusion that the "literature on the relationship of learning style and K-12 mathematics education is not broad" (p. 320). The same could be said for empirical research with post-secondary students.

A differentiated instruction study for prospective educators (Chamberlin, 2011) and two studies for students taking developmental mathematics (Garcia, 2003; Zavarella & Ignash, 2009) are three of the few post-secondary studies considering learning styles, mathematics instruction, and the enhanced use of ICT. Chamberlin (2011) studied the impact of differentiated instruction on prospective mathematics teachers taking elementary education courses from two western U.S. universities. The author reported both qualitative and quantitative results for his study of almost 100 students. The mathematics course covered operations on whole and rational numbers and the differentiated instruction considered student profile (including learning style, culture, and gender), readiness, and interests. An example of a learning experience was that students were given the definitions and common errors regarding a certain mathematics topic, followed by a formative assessment. Differentiated instruction was then used to improve and extend understanding with tiered activities as chosen by the students, based on their preferences. Formative measures of student performance included homework, quiz, tests, and project grades. When compared to a previous course given, the results demonstrated statistically significant improved mean scores in the differentiated instruction group. Students reported that this course,

> actively engaged them in making sense of the mathematics, met their different learning profiles, incorporated a variety of instructional formats, adjusted to their mathematical understandings, allowed input on their learning, offered multiple formats for demonstrating their learning, and provided individualized assignments. (p. 152)

In a study conducted by Zavarella and Ignash (2009), student learning style was used as a factor to explain withdrawal rates based on a course format. The authors noted that although studies have been undertaken to determine the impact of learning style on retention or success in computer-based instruction (CBI) (e.g., Boles, Pillay, & Raj, 1999), none had focused on students in developmental mathematics courses. An introductory algebra course was offered at a large, urban community college in Florida. As CBI was common at this multi-campus college, it was offered in three formats: (a) the traditional lecture-based, (b) the partially online hybrid format, and (c) the completely online distance format. To focus on social interaction, Zavarella and Ignash chose to use the Grasha-Reichmann Student Learning Style Scale (GRSLSS). Based on the scale, the dominant learning style for these students was found to be either collaborative or participatory. The authors determined whether this dominant learning style impacted student decision to withdraw from either the hybrid or distance delivery formats and found that it did not. Zavarella and Ignash concluded that no single format can meet all student expectations for a course, but the use of well-designed CBI may give more possibilities. The authors' suggestion that students may believe that "learning online is easy or less time consuming" (p. 10) and thus students enrolled "in developmental courses may not be cognizant of their particular learning needs" (p. 10), may indicate a need for a greater student self-awareness and metacognition. An earlier study by Garcia (2003) recognized students' unpreparedness for university level mathematics determined by placement test results. To address this concern, a developmental level course was created based on common pedagogical elements found in exemplary courses. Using a curriculum intended to enhance success, the design focused on increased use of technology, student assistance, and workshops on time management and dealing with anxiety, while at the same time, considering learning style and attitude towards mathematics. The research finding from Garcia's study was that by incorporating multiple factors for learning in a developmental mathematics course, an enhanced level of student success was achieved by students.

A review of the literature finds that learning styles have had a considerable influence in educational practice (Akbulut & Cardak, 2012), in particular for post-secondary education (e.g., Wuebker, 2013). Even though the field is complex, with confusing terminology and multiple perspectives (Coffield, Moseley, Hall, & Ecclestone, 2004) some models, like the Felder-Silverman Learning Style Model (FSLSM: Felder & Silverman, 1988) have persisted. According to Hannafin and Land (1997) "features of a learning environment (tools, resources, people, and designs) profoundly shape, direct, and constrain how learners think" (p. 194). With an expansive use of ICT (Moallem, 2007), instructors are able to provide learning experiences (Akbulut & Cardak, 2012), where an adaptive approach "is sensitive to the unique needs of each student as well as the common needs of the group" (Park & Lee, 2004, p. 651). One type of approach is aptitude-treatment (ATI), which determines instructional approach based on the identification of student learning characteristics. An understanding of the learning style of students in a developmental mathematics course meets the parameters of the ATI approach, yet the need for students to self-regulate their own learning and choose their instructional path, is uncharacteristic.

> Although teachers also need to know a student's strengths and limitation in learning, their goal should be to empower their students to become self-aware of these differences. If a student fails to understand some aspect of a lesson in class, *he* or *she* must possess the self-awareness and strategic knowledge to take corrective action. Even if it were possible for teachers to accommodate every student's limitation at any point during the school day, their assistance could undermine the most important aspect of this learning – a student's development of a capability to self-regulate. (Zimmerman, 2002, p. 65)

Self-Regulation

In the next section, I will explore self-regulation theory, the instruments used to evaluate this skill, as well as connecting self-regulated learning to an awareness of learning style and metacognition. This consideration will focus on post-secondary learners, and in particular those using ICT to learn mathematics in developmental courses.

Self-regulation theory. Self-regulation "is located at the junction of several research fields" (Boekaerts, 1997, p. 162), thus labels and terms will differ based on the individual researchers' theoretical orientation. In the 1970's, developmental psychologist John Flavell (1979) assessed research related to metacognition, or the "knowledge and cognition about cognitive phenomena" (p. 906). He developed a cognitive monitoring model based on interactions between metacognitive knowledge, metacognitive experiences, goals, and actions. From an educational standpoint, Brown, Bransford, Ferrara, and Campione (1983) found that the "active learning processes" involved "continuous adjustments and fine-tuning of action by means of self-regulating processes" (p. 116). As summarized by Zimmerman (1986),

> self-regulated learning theorists view students as metacognitively, motivationally, and behaviorally active participants in their own learning process. Metacognitively, self-regulated learners are persons who plan, organize, self-instruct, self-monitor, and self-evaluate at various stages during the learning process. Motivationally, self-regulated learners perceive themselves as competent, self-efficacious, and autonomous. Behaviorally self-regulated learners select, structure, and create environments that optimize learning. (p. 308)

Pintrich, Wolters, and Baxter (2000) further subdivided the self-regulation and control of cognition into four categories: “planning, strategy selection and use, resource allocation, and volitional control” (p. 51). Planning involves setting realistic goals for learning, including the productive use of time and the expected performance gains (Zimmerman & Martinez-Pons, 1986, 1988; Pintrich & De Groot, 1990; Pintrich, Smith, Garcia, & McKeachie, 1993). According to Pintrich (2000), self-regulated learning is “an active, constructive process whereby learners set goals for their learning” (p. 453). Although planning usually occurs at the outset, self-regulation and adjustment of goals continues throughout the performance of the task. Implementation of cognitive strategies, such as problem solving and reasoning, are central to learning (Pintrich, 1999); decisions and choice of how, when, or why to utilize these strategies are controlled by metacognition. Allocation of resources refers to how the learner manages the time and effort spent on learning. Finally, volitional control describes how the learner engages with and regulates their environment; from individual attitudes and beliefs, to how it can be structured to promote learning. For optimal effectiveness “students will often enlist the use of various self-regulation strategies” (Cleary & Chen, 2009, p. 293). Boekaerts and Cascallar (2006) emphasized the importance of self-regulated learning in education which Boekaerts, Maes and Karoly (2005) defined “as a multi-component, multi-level, iterative, self-steering process that targets one’s own cognitions, affects, and actions, as well as features of the environment for modulation in the service of one’s goals” (p. 150).

Boekaerts (1999) found that our knowledge and construction of self-regulated learning was "informed by three schools of thought: (1) research on learning styles, (2) research on metacognition and regulation styles, and (3) theories of the self, including goal-directed behavior" (p. 445) and devised a three-layer model based on regulation of processing styles, learning process, and the self, respectively. She recognized a "bidirectional relationship between learning environments and SRL" (p. 453) as one impacts the other. To adapt to a particular task, students must be aware of their learning styles, as well as "perceive a *choice* among alternative processing modes" (p. 448). Related to learning processes, Boekaerts differentiated regulation based on context, and emphasized the differences between "internal, external, or shared regulation" (p. 450). Students who regulate externally use another's metacognitive strategy to accomplish a task and may be under the incorrect "impression that they are capable of directing their own learning" (p. 450). The author concluded that student effort and choice depends on how they "construe themselves as learners" (p. 451).

What does it mean to "become self-regulated metacognitively, motivationally, and behaviorally as a learner" (Zimmerman, 2001, p. 7)? Self-regulated learners will selectively use their metacognitive and motivational strategies, to design their most advantageous learning environment, and thereby, choose the amount and type of instruction they require.

Learners and self-regulation. Students transitioning from high school to post-secondary education are "asked to be more responsible for their own learning" (Wadsworth, Husman, Duggan, & Pennington, 2007, p. 6). First-year students are given a greater selection of course choices, more control over their personal time (Ley & Young, 1998), and are expected to be more advanced in learning independently (Bembenutty, 2009; Ramdass & Zimmerman, 2011). In the transition from the structured environment of home and high school, previous regulatory strategies may no longer be applicable to “the more independent styles of learning expected” (Lowe & Cook, 2003, p. 54). In the 1990’s, American post-secondary institutions sought to broaden access by admitting students with “a variety of learning profiles, levels of preparation, goals, and talents” (Casazza, 1999, para. 22). To identify those who may potentially require additional assistance, institutions use high school grades and/or post-admission testing (Ley & Young, 1998). Not all students can control or actively manage their learning (Ley & Young, 1998; Vermunt, 1996; Weinstein, Husman & Dierking, 2000), which may be due to a lesser ability or practice of self-regulation skills (Bol & Garner, 2011; Ley & Young, 1998; 2001). Further, low-performing students are often inaccurate and perhaps overconfident when predicting their test results (Bol & Hacker, 2001; Bol, Hacker, O’Shea, & Allen, 2005). Weaker students may be unable to recognize their poor preparation, and can be less likely to use self-instruction protocols, tutors, or seek help from others (Bol, Campbell, Perez, & Yen, 2016). Developmental educators “offer many and similar anecdotal reports about the differences between developmental and regular admission students” (Ley & Young, 1998, p. 47), yet there is little empirical inquiry. In a comparison between regular admission students and those taking developmental courses, Ley and Young (1998) found significant differences in reported self-regulation strategies of first year students at both an urban community college and a rural/residential southeastern U.S. university. Both institutions used similar testing methods to assign students to either a developmental or regular admission program, from which 59 participants were randomly selected. Using the protocol developed by Zimmerman and Martinez-Pons (1986), participants were asked to describe their strategy in eight learning contexts. When responses were coded and categorized according to 15 self-regulating behaviours, those taking developmental courses scored lower than those in regular admission for both college and university. The impact of this study was the finding that "self regulating behaviours could predict developmental or regular admission status among post secondary students" (p. 53). Ley and Young (1998) suggested that educators should find ways to encourage self-regulation in students taking developmental courses. This research has been replicated in the literature in the broader scope of underprepared students in post-secondary courses (Carr, Borkowski, & Maxwell, 1991; Dabbagh & Kitsantas, 2010; Jones & Watson, 1990).

As self-regulation is a learned response (Iran-Nejad, 1990), research has shown that learners can benefit from practice (Ley & Young, 2001). A learning design which promotes instruction may increase learning outcomes for students who are less self-regulated. Ley and Young (2001) and Young and Ley (2001) presented the POME model (preparing, organizing, monitoring, and evaluating) for matching self-regulation activities to students' weaknesses. They suggested their model can act as a guideline, understanding that experienced instructors likely already use several of these activities in their practice in developmental courses. For underprepared students in a first year developmental mathematics college course, instructors can utilize homework to increase self-regulation skill (Bembenutty, 2009; Ramdass & Zimmerman, 2011). This is especially important as instructors found students lacked the self-discipline or the required resources to complete homework (Bembenutty, 2009). To reverse this trend, Bembenutty required students to self-regulate their homework activities, which resulted in increased achievement. Ramdass and Zimmerman (2011) indicated that "little research exists on how homework facilitates the development of self-regulation processes" (p. 196). They considered homework as a way for students to become more responsible by setting goals, managing tasks, evaluating work, and eliminating distractions. The research indicates that a learning intervention which utilizes activities to develop student self-regulation skills should be considered. Weaker students, who lack the ability to self-regulate, may be disadvantaged in post-secondary educational environments that require them to control and monitor their learning.

ICT and self-regulation. With the increased expansion of the use of ICT in education, it was hoped that "technology would one day be the great equalizer" (Jolly & Horn, 2003, p. 46). However, depending on the types and application of the ICT used, researchers' findings present a divergent panorama. For example, Jairam and Kiewra (2010) found that ICT did not improve learning outcomes for all as "students are not strategic studiers of computer based materials" (p. 605). In hypermedia environments (e.g., audio, video, text, Web-links, animations), Azevedo, Cromley, and Seibert (2004) and Azevedo (2005) presented arguments for use of adaptive scaffolding to "invoke self-regulatory processes that facilitate students' learning" (Azevedo, 2005, p.203). For distance education, where learning is primarily independent and based on student-content interaction, Bol and Garner (2011) expressed concern of potential failure for students with poor self-regulation skills.

Several studies have reviewed the importance of demonstrating strong self-regulatory skills for learning in online environments (Barnard-Brak, Paton, & Lan, 2010; Hu & Driscoll, 2013; Lawanto, Santoso, Lawanto, & Goodridge, 2014). Barnard-Brak et al. (2010) found that unlike those in the classroom environment, online students were required to have greater skill in both self-regulation and navigational ability. The researchers used the phrase "first-generation online learners" (p. 61) to describe students from a southwestern U.S. university whose parents, based on age, would not have learned from the Internet. The purpose of the study was to measure the development of self-regulatory learning behaviours in an online course. As none of the participants had previously taken courses in this format, enrollment and completion of the surveys were themselves the intervention. Of the 209 first year students solicited by email, 44 completed both the pre- and post-surveys, a grouping which represented 14 different academic degree programs. The authors used the Online Self-Regulated Learning Questionnaire (OSLQ) (Barnard, Lan, To, Paton, & Lai, 2009) which narrowed interest on six “important constructs in online learning” (p. 65) with higher self-regulation indicated by a higher numerical score. The authors found no significant difference between either the total score or the subscale scores pre- and post-intervention. They concluded that simply providing an online course “does not automatically help a student develop as a self-regulated learner” (p. 67). Based on their account of a gap in the literature, a study by Lawanto, Santoso, Lawanto, and Goodridge (2014) compared the self-reported regulation strategies to the actual behaviours found in a Web enhanced engineering graphics course. Their Web-intensive course was considered unique as the instructor broadcasted lectures via conferencing software, while students participated from an on-campus computer laboratory monitored by teaching assistants. Data logs were maintained in the LMS to track actual student use. Lawanto et al. administered the OSLQ and received 57 valid surveys. An important finding was that the self-regulation responses reported by students contradicted the behaviour of their online use of materials. The authors suggested “a rigorous mixed-method approach needs to be used to evaluate students’ self-regulated learning skills because this effort is a complex endeavor dealing with thoughts and actions intertwining over time” (p. 25). With the increasing number of mobile devices, tablets and smart phones visible in the classrooms, in combination with courses being offered either partially or totally online, the necessity for developing and training students in self-regulation techniques is obvious (e.g., Cho & Cho, 2014; Tsai, Shen, & Tsai, 2011). Kitsantas (2013) and Kitsantas and Dabbagh (2011) demonstrated how selected examples of the LMS and social media, respectively, can be mapped to develop self-regulatory processes.

In his recommendations for future research, Zimmerman (2013) postulated three areas of self-regulation research which require further exploration. Of note is his mention of further study focussed on computer-based learning. In addition, the author differentiates between self-regulation of learning processes (the effort required to gain understanding or skill) versus self-regulation of academic performance processes (the effort required to avoid distracting behaviours). While Zimmerman envisions a greater focus on academic performance, I believe that for students who are re-learning basic skills and concepts in mathematics, importance should be placed on the self-regulation of learning processes.

ICT, developmental mathematics, and self-regulation. A review of the research finds that training students in the use of self-regulation skills can have a positive effect on mathematics achievement (Bol, Campbell, Perez, & Yen, 2016). To provide more focus for this study, papers related to the impact of both self-regulatory learning and the particular use of ICT to achieve a greater understanding of the needs of developmental mathematics students will be considered here. These studies of developmental mathematics courses focus on multiple offerings: face-to-face (Hudesman, Millet, Niezgoda, Han, & Flugman, 2013), comparing face-to-face with a fully online environments (Spence & Usher, 2007), blended mode (McClain, 2015), and completely online (Wadsworth, Husman, Duggan, & Pennington, 2007). Hudesman et al. (2013) used formative assessment quizzes constructed to measure both mathematics and self-regulation ability for developmental mathematics students known to have had a previous poor experience. The study by Spence and Usher (2007) measured differences in the engagement of students taking a developmental algebra course at a southeastern U.S. college. In all, 164 participants were divided into two versions of the course: 88 students met face-to-face while 76 were online and met only for orientation, midterm, and final exams. All students used the same text, but the online students also used the MyMathLab courseware for instruction, practice and assignments. Multiple measures of student characteristics were taken: demographic, motivational, computer self-efficacy, self-efficacy for self-regulated learning, computer playfulness, engagement with software, mathematics grade self-efficacy, and mathematics achievement. Between the two course settings, responses were compared using *t*-tests to determine strength of student self-belief, engagement and mathematical performance, and analysis of covariance used to adjust for items of concern to the research questions. A summary of Spence and Usher's findings included the premise that it was the students' self-efficacy for self-regulation that was the greatest predictor of engagement with the online courseware. The authors concluded that for both online and traditional developmental mathematics environments, instructors must not only cultivate confidence in students but also the desire to regulate their learning. Of interest was the author's finding that students with less confidence in their mathematics ability might have chosen the online condition to prevent the need of "revealing their incompetence in person to instructors and peers in a traditional classroom" (p. 279). The recent dissertation by McClain (2015) looked at 661 students taking a blended developmental mathematics course which included both face-to-face instruction and online learning. Self-monitoring "has been described as a conscious awareness of one's behaviors" (p. 3), but the author found its use was not well documented in blended learning research. McClain compared achievement on exam and course grades with self-regulated learning level between experimental and control conditions. Multiple choice questions of completion time, work location, types of distraction, how help was sought, and overall assessment of work were used for a self-monitoring record. In the semester-long study, only students in the experimental group did these self-monitoring records, while all students completed the OSLQ survey (Barnard, Lan, To, Paton, & Lai, 2009) multiple times. Tests of

ANCOVA revealed statistically higher grades for students in the experimental group compared to the control group for the majority of the assessments. In addition, McClain found a positive correlation between the results of the final self-regulation learning survey and final course grade. This caused the author to recommend that "raising student awareness and understanding of self-monitoring, particularly when working in an online environment, may result in more substantial increases in academic achievement" (p. 132). In developmental mathematics courses, students "have encountered the information previously and have not retained it, possibly due to a lack of appropriate learning strategies" (Wadsworth, Husman, Duggan, & Pennington, 2007, p. 6-7). Due to the scarcity of pertinent research, Wadsworth et al. investigated the relationship between student performance in an online course, and the cognitive and motivational strategies they employed. Eighty-nine students taking a developmental mathematics course from a large southeastern U.S. university participated in the study. Basic algebra content was delivered completely online using a software hypermedia mathematics package (lectures, teacher videos, practice exams, and homework). Instruction was self-paced, which required students to personally regulate their choice of environment and amount of time allocated for studying. Participants were given a LASSI survey to assess learning strategies, asked to rate their confidence to determine self-efficacy when solving problems, and were graded to assess achievement. Through statistical analysis, Wadsworth et al. found that final grades could be predicted based on self-efficacy levels and the implemented strategies of motivation, concentration, information processing, and self-testing. These studies utilized the multiple modality of ICT use that is common in research related to students required to take developmental mathematics courses, and the impact that self-regulated learning may have on this key group. Further, it can be noted that due to the potentially multiple factors that influence a study of self-regulation in ICT environments (Zimmerman, 2008), it may be necessary for researchers to gain additional participant opinion related to student attitudes of themselves, the course, and their use of ICT (e.g., Wadsworth et al., 2007).

Both students and instructors can use ICT to become more metacognitively aware (Kramarski & Gutman, 2006), have tools embedded in a note framework (Cho & Heron, 2015), change student test perception (Zimmerman, Moylan, Hudesman, White, & Flugman, 2011), and increase engagement with work (Hudesman, Millet, Niezgoda, Han, & Flugman, 2013). Kramarski and Gutman (2006) made use of a method called IMPROVE (Mevarech & Kramarski, 1997; Mevarech & Kramarski, 2003), which required students to implement meta-cognitive questioning before, during, and after mathematical problem solving. In total, 65 students participated in the study which measured pre- and post-test and self-regulation questionnaire scores. Students subjected to the IMPROVE method demonstrated a significantly higher performance. Although this study used a system specific to mathematics problem solving, the important conclusion made by Kramarski and Gutman (2006) related to the challenge required in “the orchestration of the tools and activities so that the affordances of each are taken advantage of” and that “effective support needs to be distributed, integrated, and multiplied so that students have more chances to notice and take advantage of the environment’s and activity’s affordances” (p. 31). Similar to Kramarski and Gutman, Cho and Heron (2015) recommended that to give students in-the-moment strategies and motivation for self-regulation, online courseware should embed guiding questions in the notes. The authors studied the influence of motivation, emotion, and learning strategies on achievement and satisfaction of 229 students in a developmental mathematics course. Enrolled students used the Assessment and Learning in Knowledge Spaces (ALEKS) system which allowed choice of where and when (but not how) they wanted to learn. They found that motivational and emotional components significantly predicted student achievement and satisfaction with this course. The authors determined no significant difference in strategy use, and suggested this may be because the ALEKS system simply requires students to follow instructions. Students taking developmental mathematics courses at an urban technical college may not be able to “identify why they made errors or how to correct their methods of learning” (Zimmerman, Moylan, Hudesman, White, & Flugman, 2011, p. 142) when reviewing test results. In their treatment group, Zimmerman et al. gave daily feedback in the form of a quiz, which was marked immediately, and returned to students with a self-reflection form. This tool encouraged students to use “errors as learning opportunities” (p. 144); with a model of instructor process for correction and it guided students to develop self-regulatory strategies. The aim of this research was to change student perception of academic feedback to an opportunity for further learning, rather than ending at a grade point. At a large northeastern U.S. university, students were enrolled in a developmental mathematics course that utilized enhanced formative assessment, self-regulatory learning, and mastery learning (Hudesman, Millet, Niezgoda, Han, & Flugman, 2013). Instructors were educated in self-regulated learning and course counsellors observed teachers to ensure techniques were being properly used. Of interest, students were tested not only on mathematics content, but also for improvement in self-regulatory skills.

Bol, Campbell, Perez, and Yen (2016) studied 116 students taking a developmental mathematics course at a Virginian community college to determine if training in self-regulation had an effect on mathematics achievement and metacognition. Students in the treatment course completed exercises in self-regulation, including weekly setting of academic goals, reviewing checklists of study habits, managing time, and journaling. For these students, Bol et al.

established that "being in the treatment group was associated with completion of the course unit" (p. 489). By teaching self-regulation within the online environment, the aim is to change the previously held negative perceptions of students towards developmental mathematics, as they "often do not realize that they should regulate their ideas" (Kramarski & Gutman, 2006, p. 24).

Measuring self-regulation skill. There are several methods used by researchers to measure student self-regulation. One is a self-report instrument, or "any assessment tool that prompts an individual to respond to one or more questions or statements that conveys information about oneself" (Cleary, Callen, & Zimmerman, 2012, p. 3). Three common instruments in this category are the Learning and Study Strategies Inventory (LASSI: Weinstein, Schulte, & Palmer, 1987), the Motivated Strategies for Learning Questionnaire (MSLQ: Pintrich, Smith, Garcia, & McKeachie, 1993), and the Self-Regulated Learning Interview Scale (SRLIS: Zimmerman, & Martinez-Pons, 1986, 1988). The 80-item LASSI survey contains ten subscales that measure metacognition (concentration, selecting main ideas, and information processing), motivation (motivation, attitude, and anxiety) and behaviour (time management, study aids, self-testing, and test strategies). The 81-item MSLQ has two sections: learning strategies (subscales of cognitive, metacognitive, and resource management sections) and motivation (subscales of goals, course-beliefs, skill to succeed, and anxiety). To avoid suggesting potential self-regulation strategies, the SRLIS uses structured interviews to gain student responses to six different learning contexts. Participant opinions are coded and categorized into 14 self-regulatory processes. Studies using these instruments clearly demonstrated that self-regulation "was an important construct that merited further research" (Zimmerman, 2008, p. 169).

A scrutiny of the literature reveals a distinction that authors made between aptitude and event constructs of self-regulation (Cleary, 2011). The surveys and structured interviews are considered static measures of stable traits, or aptitude constructs. Perry and Winne (2006) recognized that "self-report data are the mainstay" (p. 211) of research, and give valuable information as to how individuals perceive themselves as learners. Questionnaires and structured interviews have been used in research to determine the relationship between students' self-regulatory ability and academic achievement (Zimmerman & Martinez-Pons, 1986; Zimmerman & Schunk, 2008). Researchers have found that several factors, including self-efficacy (Khatib, 2010; Kitsantas, Winsler, & Huie, 2008; Lynch, 2006; Pajares & Schunk, 2005; Pintrich & De Groot, 1990; Pintrich, Smith, Garcia, & McKeachie, 1993), learning goals and planning (Garavalia & Gredler, 2002a, 2002b; Kitsantas, 2002; Zimmerman, 2008), and management of time and study environment (Nonis, Philhours, & Hudson, 2006), are all positive predictors of increased academic performance. These studies have established the importance of self-regulation to learning and the necessity of further research related to its impact (Zimmerman, 2008). From a methodological standpoint, there are arguments against the use of self-report data, including: a) metrics (Winne, Jamieson-Noel, & Muis, 2002; Winne & Perry, 2000), b) student account reliability (Winne & Jamieson-Noel, 2002), and c) context (Hadwin, Winne, Stockley, Nesbit, & Wosczyna, 2001). Contrary to the idea of using static measurement tools, researchers consider alternate methods to "more fully capture the fluid, context-specific nature of self-regulation" (Cleary, 2011, p. 333).

Self-regulated learning is an active process that changes with the learning environment. Regardless of whether it is face-to-face, blended, hybrid or fully online, the methods of measuring self-regulation must evolve (Zimmerman, 2008) to dynamically "[capture] self-regulation processes as they naturally unfold" (Cleary, Callan, & Zimmerman, 2012, p. 1). Some examples used by researchers include: a) behavioural trace logs (Perry & Winne, 2006; Winne, Nesbit, Kumar, Hadwin, Lajoie, Azevedo, & Perry, 2006), b) think-aloud protocols (Azevedo & Cromley, 2004; Azevedo, Cromley, & Siebert, 2004), c) structured diaries (Schmitz & Wiese, 2006), d) direct observation (Perry, Vandekamp, Mercer, & Nordby, 2002) and e) microanalytic measures (Clearly, 2011; Cleary and Chen, 2009; Kitsantas & Zimmerman, 2002). Dynamic measurements may require specialized software or detailed protocols to assess student self-regulation skill, and many methodologies are in the trial state (Zimmerman, 2008). Winne and Perry (2000) and Winters, Greene, and Costich (2008) surmised that as a study of self-regulation is complex, the use of one or more methodological approaches to triangulate results may provide conditions for a more detailed analysis.

In conclusion, many studies use students' ability to self-regulate to predict or justify academic achievement. As students transition from secondary school to college, they must take on a greater responsibility for learning and their independent life skills. Further, with the rapid onset of online environments, students are required to regulate choice of activities, especially in a developmental mathematics course. Particularly for these learners, the literature demonstrates the necessity of developing good self-regulatory habits, yet many studies offer little assistance in modelling supportive pedagogy.

Conclusion

This literature review gave a context for the community college landscape and the role of developmental mathematics within the framework. In addition, a review of the literature pertaining to student self-awareness and self-regulation, although demonstrating depth, provides a backdrop for the importance of further research requirements. As a detailed review of the literature did not provide ample evidence that current research addresses a) Ontario community college students taking foundational mathematics courses, b) the impact of affordances provided by enhanced use of ICT, and c) the teaching strategies that emphasize self-awareness and self-regulation, the need for this study is apparent.

CHAPTER THREE

RESEARCH DESIGN AND METHODOLOGY

The previous chapter described the limited classroom research in Ontario community college settings, in particular with developmental mathematics students. As adults, these students are expected to be responsible for their learning, which can be accomplished with a greater self-awareness of learning style and ability to self-regulate. This chapter describes the methodology: details of the research design and participants, data collection and analysis procedures, and ethics considerations. The purpose of this study was to utilize the affordances provided by an investigator-designed learning intervention to develop increased self-awareness and self-regulation of first year community college students in a foundational mathematics course.

Research Questions

This study was designed to address the following three research questions:

1) How do the affordances provided by the learning intervention that are perceived to support metacognition (i.e., self-awareness and self-regulation) enhance self-regulation of students in a foundational mathematics college course?
2) How do student demographic factors (e.g., age, gender, and ethnicity) and attitude towards learning mathematics with technology relate to their utilization of the affordances of the learning intervention in a foundational mathematics course?
3) How does learning style, based on the active or reflective dimension, relate to student demographics, attitude toward mathematics, self-regulation, and choice of artefact in the learning intervention designed for students in foundational mathematics courses?

Research Design

The study used a mixed–methods research design. A strictly quantitative study was deemed as inappropriate since it investigates the who, the where, and the how many (Adler, 1996), but does not examine the why or the how (Ross & Onwuegbuzie, 2012). On the other hand, as qualitative research is “typically based on small, nonrandom (i.e., purposive) samples” (Onwuegbuzie & Johnson, 2004, p. 441), it may not be generalizable to a larger population (Ross & Onwuegbuzie, 2012). Thus, “mixed methods research is an intellectual and practical synthesis based on qualitative and quantitative research” which provides “the most informative, complete, balanced, and useful research results” (Johnson, Onwuegbuzie, & Turner, 2007, p. 129). A mixed-methods perspective for mathematics education allows the researcher to assess “tangible and intangible variables, as related to improvement of students’ mathematical understanding” (Ross & Onwuegbuzie, 2012, p. 105). Although this study did not seek to measure a change in mathematical understanding, it can be classified as quantitative-dominant, as it relies on a quantitative data collection, tempered with qualitative data to augment findings (Johnson et al., 2007). Collins, Onwuegbuzie, and Sutton, (2006) described four rationales commonly used for mixed-method research, of which this study used significance enhancement. Significance enhancement mixes techniques “for the rationale of enhancing researchers’ interpretation of the data” (Collins et al., p. 83). In addition, by using mixed techniques either “concurrently or sequentially within the same study” (Ross & Onwuegbuzie, 2012, p. 89), a researcher can realize Greene, Caracelli, and Grahman’s (1989) purpose of complementarity, as “qualitative and quantitative methods are used to measure overlapping but also different facets” (p. 258). In conclusion, I followed the suggestion of Ross and Onwuegbuzie (2012) to find ways to "optimize [my] mixed methods research [design]" (p. 105), so that it best meets my research needs.

Research Setting

The Mathematics Foundations for Technology (MFT) course prepares students to take first and second year mathematics in the School of Biological Sciences and Applied Chemistry (SBSAC) within the Faculty of Applied Science and Engineering Technology (FASET) at Seneca College. In addition to admission testing, students within technology programs are required to take a mathematics placement test (Canadian Achievement Test, CAT3 – level 19). Those who obtain a grade lower than a certain cut-off point (approximately 30% of students per year) are enrolled in this non-credit MFT course. Students take this course for one-semester (14 weeks), having six hours of instruction per week (three two-hour sessions). It provides a review of arithmetic procedures (fractions, decimals, percent, and measurement), which gradually evolves into developing algebraic concepts (algebra and word problems), and then moves to graphical representations and applications (graphing skills, geometry, and trigonometry). Examples given for practice relate to chemistry and biology fields and students must obtain a grade of 50% or greater (satisfactory) to pass. Since 2011, MFT has been taught in hybrid mode: two sessions offered as face-to-face instruction, and one hybrid session where students are encouraged to learn online in their preferred environment. As well as mathematics, students learn the use of: a digital stylus on a tablet PC, DyKnow Vision software, the learning management system (LMS), Microsoft Outlook 365 email, resources provided by the college (e.g., library, learning center, tutoring, and counseling) and the instructor (email, online textbook, worksheets, and course documents).

Face-to-face sessions

Beginning in 2010, the MFT course has been offered in a 40 seat pen-based tablet PC laboratory setting, unique within Seneca College. New for this research, was the use of 40 Microsoft Surface (MS) Pro 3 tablet PCs, an upgrade from the past use of the HP Elitebook tablet PCs. For input the MS Pro 3 PC uses three interfaces: touch, stylus/mouse, and keyboard. Like using a ballpoint pen on paper, the stylus digital ink is fluid, smooth, and precise, making it ideal for handwriting mathematics on a computer screen. Due to the palm blocking technology, students can rest their hand directly on the screen without any interference with their writing.

In the MFT tablet laboratory, students share a common virtual workspace (the class notebook) through the use of DyKnow Vision software. Before class, instructors develop their note framework from a resource made available to them through the LMS. Once they have designed their MS Word document, it is sent to the DyKnow virtual printer, converting the class notebook into a form that can be opened in the software. The DyKnow software is original as it was developed for pen-input devices, so rendering is exact and takes only seconds. In this form, each page of the MS Word document is converted to a single panel in DyKnow. A panel looks similar to a Word document but differs in the features located in the interactive ribbon (see Figure 1). The interactive ribbon gives students pen/highlighter colour and thickness options, the ability to submit a panel(s) to the instructor, and to save their notes. By touching the stylus to the eraser icon, the pen takes the role of an eraser and can remove undesired work, but not the instructor notes. A larger pane makes up the central area, where the class notebook information appears, with reverse and forward arrows allowing students to control panel flow. Two smaller panes give students the option to make personal notes and use the communication and feedback features of the software (chat, messaging, and the ability to send a red-yellow-green notification to confirm understanding).

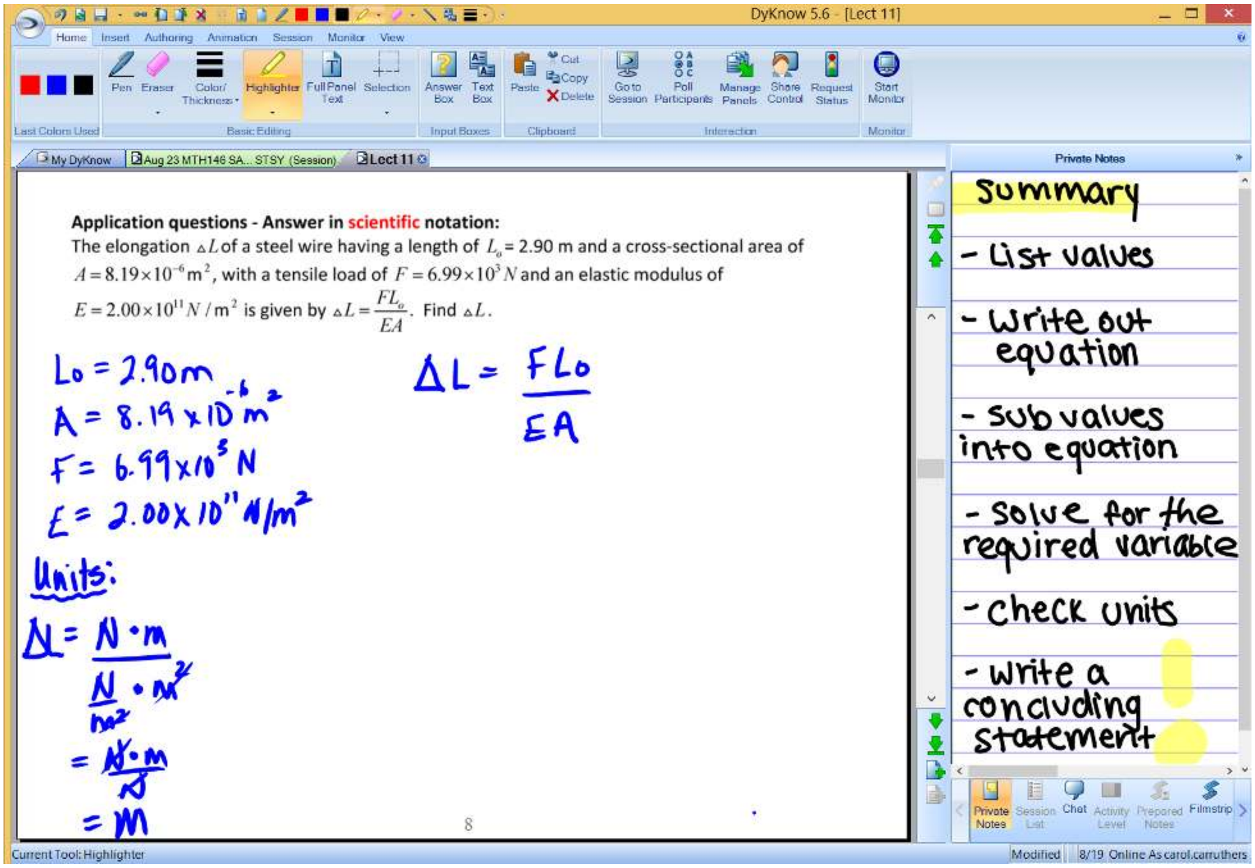


Figure 1. A DyKnow Vision panel with an interactive ribbon above, a central larger pane for class notebook information, and two smaller panes for student personal notes and communication.

During the face-to-face sessions, students synchronously log into the DyKnow software, where a message is waiting asking them to join the session. In addition, students open their course site for ongoing orientation of available resources and immediate access to the online textbook. As the instructional panel is shared, students can synchronously watch their personal screens and listen while the teacher (or other students) explain and solve problems. This ensures that they have correct solutions completed by the instructor or fellow students, as well as their own work. Students can annotate their main panel, highlight important comments, and make summaries on their personal notes. Interactive activities such as live links to websites or textbook, communication tools such as polling, chat, and sending panels to the instructor for immediate anonymous feedback, as well as collaborative features like sharing panels and online groups, are commonly used during each class session. At the end of the allotted time, the class notebook has been personalized by each student, contains teacher and fellow student solutions, screen captures of important information, summary notes, additional questions added 'on the fly', as well as the persistent live links to additional resources. Students save the class notebook (date and time stamped) to a server for future access via the Internet.

Hybrid sessions

As a hybrid session occurs outside of conventional face-to-face instruction, students choose when and where they prefer to learn by asynchronously logging into the LMS and working through prepared activities. With the use of quizzes provided in the online textbook and resource links, students can obtain immediate feedback of their understanding and skill.

Sampling and Recruitment

Participants in this study were the first-year students enrolled in introductory courses (biology, chemistry, mathematics, English, and computer studies) during the spring semester. A complete explanation of research rationale was given to students and the potential advantages and disadvantages of participating were clarified. No active recruitment of participants was necessary, as all students in MFT were required to do the intervention procedures as part of the course. Students (a) were informed by the instructor reading a prepared script (see Appendix A), (b) were given an opportunity to have questions answered, and (c) each received a hard copy of the invitation and Consent to Participate in Research form to sign (see Appendix B). They kept the invitation letter for their records, but were asked to return the informed consent form to an envelope they sealed (regardless of signature). Students were made aware that consent forms would be maintained in a locked cabinet until after the instructor's grades had been submitted. Twenty students were enrolled in the MFT course, 18 gave consent to participate, of which 17 provided utilizable data.

After the study was completed and final marks were submitted, the instructor/researcher reviewed the informed consent documents (see Appendix B) and invited eight students to participate in individual, semi-structured interviews related to the learning intervention. The interview participants were selected based on their learning style (active/reflective), regular attendance during the four class activities (A-D), age (younger/more mature), and gender (M/F) to gather a range of opinions. Before the interview began, the researcher answered questions, and asked participants to read and sign the Consent for Interview and Audio Recording letter (see Appendix C). Participants were informed that the interview would be audio recorded and transcribed. Due to the time constraints of the study, six students were interviewed.

Data Collection Procedures

The learning intervention

For this study, the learning intervention consisted of students completing surveys, developing studynotes and screencasts, and using scaffolded learning materials delivered either face-to-face (through a classroom learning system DyKnow software utilizing pen-based tablet PC computing) or asynchronously (through the LMS). The instructional time was modified so that rather than being in hybrid, students came to class for the two additional hours per week, so that research activities could be accommodated (see Table 1). As well as mathematics instruction, teacher notes were scaffolded with information for students to help them to better understand their learning style and develop self-regulatory skills. All surveys and activities were conducted during instructional time, as per the schedule in Table 1.

Table 1

Outline of the Research-Related Procedures for this Study

Phase	Week	Description
Pre-intervention	Wk 1	Explain research intent Consent requested Index of Learning Styles (ILS)* survey administered and analyzed
	Wk 2	Survey package administered** ILS survey findings and meanings shared with individual students Course notes redesigned – content embedded with self-regulation skills modeled
Intervention	Wk 3	Activity A – Studynote on order of operations, fractions, and proportions Student activity survey A Student studynote artefacts collected Learning Management System (LMS) activity tracked
	Wk 4	Activity B – Screencast on proportion, metric measurement, and conversion Student activity survey B Student screencast artefacts collected LMS activity tracked
	Wk 5	Activity C – Studynote and Screencast on conversion Student activity survey C Student studynote and screencast artefacts collected LMS activity tracked
	Wk 6	Activity D – Studynote or Screencast on conversion, rounding, scientific notation, and percent Student activity survey D Student studynote or screencast artefacts collected LMS activity tracked
Post-intervention	Wk 6	OSLQ survey re-administered
	Wks 7-8	No classes
	Wks 9-12	Interviews

*Index of Learning Styles (43 items, see Appendix D)

**The package consisted of demographics (9 items, see Appendix E), Mathematics and Technology Attitudes Scale (MTAS) (20 items, see Appendix F), and Online Self-regulated Learning Questionnaire (OSLQ) sections (24 items, see Appendix G).

The pre-intervention phase of data collection consisted of two parts, the invitation for research and administration of the ILS and the survey package.

The following surveys were administered:

Index of learning styles (ILS). To provide an opportunity to develop self-awareness, individuals were asked to complete an ILS questionnaires (Felder & Soloman, n.d.) which, as described in the previous chapter, had respondents categorize themselves along the four dimensions of a scale measuring their: (a) sensory or intuitive perception, (b) visual or verbal input, (c) active or reflective processing, and (d) sequential or global understanding (see Appendix D). The ILS questionnaire is a 44-item survey which does not indicate one's learning strengths or weaknesses, only their preferred learning style (Felder & Spurlin, 2005). Zywno (2003) conducted research on the efficacy of using the ILS, and found that the instrument had strong to moderate reliability, indicating consistent and repeatable results, and was within acceptable limits for validity. In this study, findings from the ILS were shared with participants, with an explanation of meaning to cultivate dialogue and develop awareness of alternate learning strategies. The researcher obtained permission to use the ILS instrument from Dr. Richard M. Felder.

Demographic survey. Students were requested to complete a demographic survey to obtain background information and learn about individual's mathematics and educational experiences (see Appendix D). Survey items were based on the 'Learner Demographic and Characteristics' section from the Colleges Ontario Student and Graduate Profiles, Environmental Scan, 2014.

Mathematics and technology attitudes scale (MTAS). The MTAS (Pierce, Stacey, & Barkatsas, 2007) was used to gain introductory knowledge of students' attitudes towards mathematics, technology, and the use of technology to learn mathematics (see Appendix F). The MTAS instrument uses a 5-point Likert-type response format to address 20 items categorized into five sub-scales: (a) mathematics confidence, (b) confidence with technology, (c) attitude to learning mathematics with technology, (d) affective engagement, and (e) behavioural engagement. The authors base their definitions of the survey subscales from the works of both Vale and Leder (2004) and Galbriath and Haines (1998). Pierce et al. (2007) defined the meaning of MTAS subscales in the following way:

> (a) mathematics confidence, as the "students' perception of their ability to attain good results and their assurance that they can handle difficulties in mathematics" (p. 290);
>
> (b) technology confidence, as they are self-assured, can master, and are more confident when they are operating and being supported by using computers;
>
> (c) learning mathematics with technology, as the students' attitude towards how much using a computer facilitates, makes mathematics learning relevant, and enables their achievement;
>
> (d) affective engagement, as how students "feel about the subject" (p. 292); and
>
> (e) behavioural engagement, as "what students do to learn in class" (p. 292).

The MTAS survey was modified to reflect the current use of ICT, and adapted using feedback from college instructors who had previously taught the MFT course in hybrid mode. The behavioural engagement set of questions used a 5-point Likert scale related to frequency of occurrence (1 = "hardly ever", 2 = "occasionally", 3 = "about half the time", 4 = "usually", and 5 = "nearly always"). All other subscales used a 5-point Likert scale (1 = "strongly disagree" to 5

= “strongly agree”). The researcher obtained permission to use the MTAS instrument from Dr. Robyn Pierce.

Online self-regulated learning questionnaire (OSLQ). The OSLQ (Barnard, Lan, To, Paton, & Lai, 2009; Barnard, Paton, & Lan, 2008) was used to measure students’ self-regulatory skill both before and after the intervention (see Appendix G). The OSLQ instrument also uses a 5-point Likert-type response format to address 24 items categorized into six sub-scales: (a) environment structuring, (b) goal setting, (c) time management, (d) help seeking, (e) task strategies, and (f) self-evaluation. Barnard et al. (2009) concluded that the advantage of using this survey was that “it expands self-regulation research into the online learning domain” (p. 5), as their study found “evidence toward the reliability and validity of the OSLQ to assess the self-regulatory learning skills of students enrolled in both blended and online course formats” (p. 5). For this study, college instructors provided feedback to update and modify the OSLQ. It was then administered to students both pre- and post-intervention to quantify the overall change, and to measure differences in each of the subscales, related to self-regulation. The researcher obtained permission to use the OSLQ from Dr. Barnard-Brak.

Activities (A - D). During the intervention phase, all students participated in four activities. Common for all activities were the following aspects:

1. For Activity A - D materials were made available in a content area labelled ‘RESEARCH’ on the MFT course site of the LMS. For Activity A all materials were also printed, for activities B, C, & D only the Activity Surveys were printed.
2. For Activities A, C, & D, a studynote was a one page document that reviewed the basic concepts required to solve a mathematics question, then gave a step-by-step explanation of the solution to one or more problems. Studynotes were constructed using an MS Word

Document and the stylus of the MS Pro 3 tablet PC. Features of tablet use included handwritten annotation using a choice of pen/highlighter colour and thickness. Request to keep the length of a studynote to only a single-page required participants to plan, arrange, and execute work.

3. For Activities B, C, & D, a screencast was an audio-visual recording of the computer screen while a mathematical problem was solved in a step-by-step manner. The technique was similar to that described for a studynote, with the difference that pen stroke motion was captured simultaneously with audio explanation of the process.
4. For Activity A, participants emailed or copied their artefacts to a flash drive for submission. For Activities B, C, & D, participants submitted artefacts to a collection site (similar to a dropbox), a folder within the RESEARCH content area. The instructor collected participant artefacts by email or on a flash drive. Students were made aware that submitted artefacts would be commented on and annotated by the instructor, and posted to the RESEARCH content folder for the use of their classmates. Data were collected using the LMS tracking which recorded the number of times these folders were opened by individual students, specifically by date of use.
5. All students were requested to participate in Activity Surveys unrelated to number of artefacts completed. Participants used a coded identification, and placed responses into an envelope, which was sealed and securely stored for later analysis.
6. Student attendance was taken for all activities.

Each activity had specific components, as described below:

Activity A. Scaffolded materials for studynote preparation consisted of:

1. Practice questions for quiz preparation. Mathematics topics included: number classification, number lines, exponent laws, order of operations, fraction and proportion operations and word problems (see Appendix H).
2. An instructor-written studynote that demonstrated solving a fraction question (see Appendix I).
3. Instruction on how to write a studynote, including an explanation of use of a stylus on a Word Document and how to save and export work (see Appendix J).
4. An Activity A Survey (see Appendix K).

During instructional time, students were asked to work either individually or in groups to solve the practice questions. After 15 minutes, the instructor requested that students view the instructor-written studynote, and complete the first page of the Activity A Survey. After the instructor clarified the purpose and use of a studynote, the students were asked to choose one question from the practice (or design their own), solve, write their solution as a studynote, and submit. Students were asked to finish Activity A Survey.

Activity B. Scaffolded materials for screencast preparation consisted of:

1. Practice questions covering mathematics topics of: ratio and proportion, measurement, and conversions (see Appendix L).
2. An instructor's example of a screencast. The mathematical content demonstrated a conversion of metric units (see Appendix M).
3. Instruction on how to create a screencast, including explanation of how to use the Screencast-O-Matic software and microphone headsets (see Appendix N). Some students supplied their own headsets.
4. An Activity B Survey (see Appendix O).

The protocol was similar to that for Activity A, with the exception that the produced artefact was a screencast. Demonstration and clarification of software use was given. Students first practiced, then recorded their solutions. The software afforded pausing to collect thoughts, or a quick re-start if required. The instructor asked students to provide an organized and clear solution.

Activity C. Request for both a studynote and a screencast consisted of:

1. Practice questions of the mathematics topic of conversion were given for homework prior to Activity C (see Appendix P).
2. An Activity C Survey (see Appendix Q).

The protocol was similar to previous activities. For Activity C, students were requested to complete both a studynote and a screencast. Instructor provided instructions were reduced or faded. The self-regulatory skills required to complete a more detailed process were discussed.

Activity D. Choice of either a studynote or screencast consisted of:

1. Homework practice questions of the mathematics topics of: conversion, ordinary and scientific notation, rounding, significant digits/figures, and percent were given (see Appendix R).
2. An Activity D Survey (see Appendix S).

The protocol was similar to previous activities. For Activity D, students were requested to complete either a studynote or a screencast, dependent on which they felt suited their learning needs.

In the post-intervention phase, the OSLQ (Barnard, Lan, To, Paton, & Lai, 2009) was re-administered, and the semi-structured interviews were conducted.

Semi-structured interviews. Hanson, Creswell, Plano Clark, Petska, and Creswell (2005) suggested that data collected by interview can be used to “corroborate, refute, or augment findings from the survey data" (p. 227). Semi-structured interviews in particular, are "to be delivered mostly in a set order, but with some flexibility in the questions asked, the extent of probing, and question order" (Rowley, 2012, p. 262). Individual semi-structured interviews were conducted in the schools' on-campus private boardroom, between classes during the school day, at the participants' convenience. The interview questions were based on the research parameters, and developed as Jacob and Furgerson (2012) recommended, from practicing with a friend, an uninvolved party, and with faculty (who had previously taught MFT). Before the interview began, a hard copy of all questions was given to participants, for their referral during the interview (see Appendix T). During the interview process, only brief field notes were taken so the interviewer could give full focus to the responses, and provide prompts as necessary. Interviewer prompts depended on participant responses and allowed the researcher the opportunity to ask additional questions, to clarify some statements, and to further explore their experience (Kennedy, 2006). For transcription of individual audio files to a Word document, participants were identified by their four digit numeric/alpha code, and all subsequent documentation used this code.

Throughout the research process, the instructor/researcher maintained a personal reflection journal. The instructor made entries based on class observations to provide reference and context. Throughout the intervention, the instructor re-designed class notebooks with content as well as features to enhance self-regulatory skills (see Appendix U).

Data Analysis

Data analysis integrated quantitative and qualitative data in a non-sequential order to validate findings. Integration was done during the interpretation phase by examining the quantitative and qualitative results for significance enhancement and complementarity (see Figure 2).

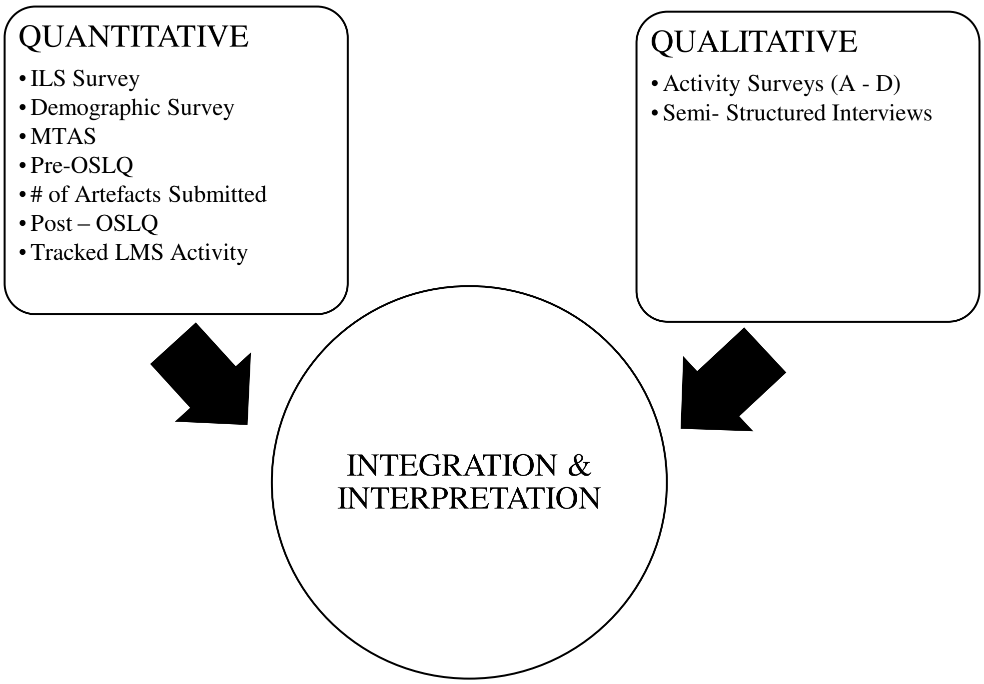


Figure 2. Data analysis process model for this study.

In this mixed-methods research design, data collection was primarily quantitative, while qualitative data were used to gain a clearer perspective and an explanation in participants' words. Sequencing of data collection adhered to a prescribed timeline (see Table 1), with most quantitative data collected in the pre-intervention phase, followed by collection of both quantitative and qualitative data in both the intervention and post-intervention phases.

During the intervention. The ILS instrument (Felder and Soloman, n.d.) was analyzed immediately following data collection (see Appendix D). The ILS has four dimensions (sensory or intuitive, visual or verbal, active or reflective, and sequential or global), representing a continuum between opposite characteristics or poles. The final score for each dimension was calculated by summing responses for each pole and calculating the difference. The direction of the pole was determined by the one that had the largest number of responses, the strength for that tendency depended on the magnitude of the difference. An example is given for the active or reflective dimension (see Figure 3).

Reflective Pole	-11 to -9 Strong Reflective	-7 to -5 Moderate Reflective	-3 to -1 Mild Reflective	1 to 3 Mild Active	5 to 7 Moderate Active	9 to 11 Strong Active	Active Pole

Figure 3. Scoring for the active or reflective dimension based on the ILS Scoring Sheet and Report of Results (Felder & Soloman, n. d.)

The ILS Scoring Sheet and Report of Results were downloaded from the Internet (Felder & Soloman, n. d.), copies were made, and individual results were confidentially given to the participants. Following the survey, the instructor/researcher conducted an in-class discussion to increase students' awareness of their learning styles and the learning styles of others.

After the intervention. As the researcher was also the instructor, data analysis (with the exception of the ILS) did not commence until after student grade submission. All surveys and documents were coded using an alpha numeric code, gathered in sealed envelopes, and stored in a locked file cabinet in the instructor's personal office.

The initial survey package included hard copies of the Demographic Survey (see Appendix E), MTAS (see Appendix F), and the OSLQ (see Appendix G). The OSLQ was administered to participants with the survey package (pre-intervention) and again after the intervention (post-intervention). Paper survey responses were first manually inputted into MS Excel and then imported into SPSS (v. 22.0). During analysis, it was noted that three students may have omitted responding to some questions (e.g., missed the back page of the survey). Following the advice of George and Mallery (2014) for missing responses, "for continuous data a frequent procedure is to replace values with the mean score of all other subjects for that variable" (p. 66) the value for this item was replaced with the mean score for the items. Further, one item (question #16 of affective engagement) of the MTAS survey was omitted during printing of the hard copy for distribution to participants. The value for the missing question was calculated using the average of the other three responses in the subscale.

The demographic survey was analyzed using the descriptive statistics feature of the software to calculate frequencies. Each MTAS subscale score consisted of the responses to four items, and with a minimum score of one and maximum of five, added scores had a range in value from 4 – 20. Following Pierce, Stacey, and Barkatsas (2007), a median score of 17 or greater was considered "a very positive attitude", a score of 13-16 was moderately high, and a score of 12 or less was considered "a low score reflecting a neutral or negative attitude to that factor" (p. 294). In SPSS, the mean values for each subscale were computed. The OSLQ was delivered both pre- and post-intervention. In SPSS, descriptive statistics of mean and standard deviation were calculated. Total self-regulated learning score was calculated by summing responses to all items and dividing by number of questions (24) to determine the mean and standard deviation. Mean subscale scores were similarly calculated. According to Barnard-Brak, Paton, and Lan, (2010) "higher scores on this scale indicate higher levels of self-regulation in online learning" (p. 65).

Attendance was taken for all activities (A-D). For the number of studynotes and screencasts submitted, data were analyzed using descriptive statistics of frequencies, means, and standard deviations. Artefacts from each activity were posted by the instructor in separate files into the RESEARCH content area. Within the LMS, the researcher tracked the number of times students viewed each file for a period of 31 days following its posting. Due to constraints of the LMS tracking system, it was not possible to measure the length of time each student spent viewing the four artefact files (Activities A-D), nor was it possible to determine which items they viewed, and if students had downloaded or saved any of the items to their personal computer.

Qualitative data were gathered in two formats, by student submission of activity A – D surveys, and by semi-structured interviews. The activity surveys (see Appendices K, O, Q, and S) included both closed response (multiple choice) and open-ended questions. The researcher compiled the open-ended responses from the activity surveys onto an Excel spreadsheet. For the semi-structured interviews, open-ended response questioning gave the researcher the opportunity to delve more deeply into a participant's personal experience (Teddlie & Tashakkori, 2009). For example, as an interviewer, the researcher could clarify meaning, recognize subtle nuance, and ensure accuracy from this dynamic interaction with the participants. Analysis captures "the complexities of meaning within a textual data set" (Guest, MacQueen, & Namey, 2011, p. 11) and can be administered in various forms. Methods used for qualitative analysis can be broadly divided into two groupings; those that are dependent on an epistemological position and those that can be applied across several theoretical approaches. Thematic analysis takes a researcher from observation to understanding as "recognizing an important moment (seeing) precedes encoding it (seeing it as something), which in turn precedes interpretation" (Boyatzis, 1998, p. 1). Braun and Clarke (2006) defined thematic analysis as "a method for identifying, analysing and reporting patterns (themes) within data. It minimally organizes and describes your data set in (rich) detail" (p. 79) and suggested it "is the first qualitative method of analysis that researchers should learn" (p. 78). The advantage of thematic analysis is it "provides a flexible and useful research tool, which can potentially provide a rich and detailed, yet complex, account of the data" (p. 78). In this study, data analysis for both the activity surveys and the semi-structured interviews was categorized as follows:

Data corpus. Braun and Clarke (2006) define the data corpus as "*all* data collected for a particular research project" (p. 79). Interviews were audio recorded and the researcher listened to each, in their entirety, two to three times. While listening, brief notes were made and comments of interest were noted. Transcriptions were typed into an Excel spreadsheet by the researcher, and simple notes were taken of phrases of interest in the moment. A greater understanding of meaning was obtained by the researcher conducting the individual interviews, listening to the data, and transcribing the audio to text.

Data item. A data item is described as "each individual piece of data collected" (Braun & Clarke, 2006, p. 79) which combine to make the data corpus. Data were organized chronologically within the Excel spreadsheet and then segmented. The technique of segmentation is used to "assess and document…and facilitate the exploration of thematic elements" (Guest et al., 2011, p. 50). The researcher first separated the text into responses by question, then divided those into various cohesive elements.

Data extract. Braun and Clarke (2006) define a data extract as "an individual coded chunk of data" (p. 79). After becoming familiar with the data, the researcher coded the information in various ways. What emerged from this process was a specific focus to the given intervention. Text was coded into the five subscales of the MTAS (mathematics confidence, confidence with technology, attitude to learning mathematics with technology, affective engagement, and behavioural engagement), the six subscales of the OSLQ (goal setting, environment structuring, time management, task strategies, help seeking, and self-evaluation), active or reflective learning styles, and the participants' mention of ICT.

Decisions about themes. From the coding, student's attitudes and self-regulation were determined as themes. What originally appeared as outlying comments indicating a greater understanding of how students were thinking about their learning (and perhaps in different ways), were collected as a Self-Awareness Theme. All mentions of technology were coded with the data extract, and resulted in an additional theme, called Affordances of the ICT. This is primarily a deductive method, which "tend[s] to be driven by the researcher's theoretical or analytic interest in the area, and is thus more explicitly analyst driven" (Braun & Clarke, 2006, p. 84).

Data set. A data set "refers to all the data from the corpus that are being used for a particular analysis" which is "identified by a particular analytic interest" (Braun & Clark, 2006, p. 79). To analyze the themes that emerged, data sets were developed based on research questions. Within the data set, extracts were compiled to generate meaning.

The research questions. The first research question related to the development of individual self-regulation skill by students. This skill was measured using the OSLQ responses of the participants both before and after the intervention. The learning intervention provided students with a multimedia environment with the enhanced use of the ICT. This question attempted to gain a greater understanding of the affordances of the ICT, in particular as related to developing student awareness and self-regulation ability. A paired sample *t*-test was used to compare two matched samples across a time interval (pre- and post-intervention conditions). The null hypothesis assumed the two means of the paired samples were equal. A .05 level of significance was used. Cases included determination of significant differences in total self-regulation skills, as well as for each of the subscales (goal setting, task strategy, time management, environment structuring, help seeking, and self-evaluation). Histograms for each of the above mentioned cases were created to view possible trends. For qualitative analysis, data sets using themes of self-awareness, self-regulation and affordances were considered. Data extracts were organized in separate tables and converged to provide examples in support for answering the first research question.

The second research question examined how demographic factors and attitude toward learning mathematics related to how students used the affordances provided by the learning intervention. Students produced either studynote or screencast artefacts for a period of four weeks. As the artefacts were posted to the LMS, usage within the LMS was traced to find number of views by students. This study used the number of studynotes and screencasts either produced or viewed as a measure of the utilization of the affordances of the learning intervention by participants. Descriptive statistics of frequencies were used to measure percentage of studynotes and screencasts produced. Number of views by students for a period of 31 days following posting were tracked in the LMS, and means and standard deviations calculated. A Pearson bivariate correlation was used to find correlation between the number of views of the artefacts to their type (i.e., a studynote or screencast). To gain an understanding of when students were using the provided artefacts, a graph summarizing usage by date was produced. To answer the second part of the question, a Mann-Whitney U statistical test was used to determine if demographic factors of age, gender, or ethnicity impacted utilization of the affordances of the intervention. Age was categorized as 25 years or younger and greater than 25 years, and ethnicity as those that self-identified as Asian or other. The Mann-Whitney U test is based on ranked scores, and determines if two groups are different from each other (George & Mallery, 2014). A Mann-Whitney U test compared the utilization by artefacts submitted. A Pearson correlation was used to determine if viewing of the artefacts depended on age, gender or ethnicity of students. The results from the MTAS was used to gain a background understanding of student’s attitude towards using mathematics with technology. An independent samples *t*-test compared age, gender, and ethnicity to the scores created through the MTAS subscales. A qualitative analysis of student survey and semi-structured interview used only data extracts related to studynotes and screencasts.

For research question three, the focus of the analysis was on learning style (active or reflective dimensions) in relation to demographics, attitude, self-regulation, and affordances of the learning intervention. Descriptive statistics of frequency was used to obtain a representation for the active or reflective learning styles of the participants. An independent-samples *t*-test was used to assess the impact of demographics of age, gender, or ethnicity. A Shapiro-Wilk test was used to determine if data in these categories had a normal distribution. The influence of attitude was visualized using trends from scatter plots. The difference of the means between the post- and the pre-intervention self-regulation scores were plotted against active and reflective dimensions to observe a trend. The number of studynotes and screencasts submitted by more active versus more reflective students was calculated and compared using independent samples *t*-test. Finally the student activity surveys and semi-structured interviews were analysed using data sets from self-awareness as related to the affordances of studynotes and screencasts.

To aid in the integration and interpretation of data, the instructor's reflective journal was used as a reference.

Ethical Considerations

The research study was reviewed and approved by the Seneca College Research Ethics Committee and the University of Windsor Research Ethics Board (see Appendices V and W) to ensure ethical standards were maintained. As a requirement of University of Windsor Research Ethics Board, the researcher completed the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans Course on Research Ethics (TCPS 2: CORE) (see Appendix X).

There was a concern that the choice to participate may have impacted the course mark, as the researcher was also the instructor. Students were assured that their participation in this research would not influence their grades (see Appendix A). Personal randomly generated four digit numeric/alpha code were given for identification on surveys (ILS, demographic, MTAS, OSLQ, and Activity A-D Surveys). All surveys, with the exception of the ILS, were collected in an envelope, sealed and stored in a locked file drawer in the researchers' personal office. The responses from the ILS were analyzed and an individual learning style profile confidentially shared with each student. Students were made aware that submissions of studynotes and screencasts for Activities A – D would be annotated by the instructor and posted to the RESEARCH content area for viewing by classmates. Artefacts were posted by title or content only, although some students may have chosen to identify themselves. Once instructor grades were submitted, files were transported securely to the researchers' residence for analysis, and kept in a locked file drawer. Interviews were recorded on password protected devices, an SD card was kept securely. During the analysis process, data were compiled on the researcher's personal password protected computer, in encrypted files.

This chapter described the research design, procedures, and data collection tools used to evaluate the impact of a learning intervention. It gave detailed description of how data were analyzed using both the quantitative and qualitative perspectives. In the next chapter, the integration and interpretation of results will be offered, as well as preliminary thematic elements as they pertained to each research question.

CHAPTER FOUR

RESULTS

The purpose of this study was to explain how students in a first-year community college foundational mathematics course utilized the affordances provided by a learning intervention designed to increase their self-awareness and self-regulation. This chapter presents the analysis of data gathered through questionnaires, four activities, student interviews, and a researcher journal kept throughout the study. It is structured to explore the three research questions.

Participants

The participants in the study consisted of 17 students enrolled in a Mathematics Foundations for Technology (MFT) course. As presented in Table 2, over half of the participants were female (n = 10, 58.8%) and seven were male (41.2%). The majority of participants were 25 years of age or younger (n = 12, 70.6%), and more than half of them (58.8%) identified their first language as other than English or French. In addition, nine participants (53.0%) self-identified as Asian/South Asian/Southeast Asian and eight as other (Caucasian, Caribbean/West Indies, and Black). Seven participants in this study entered college directly from high school while 10 participants either experienced delay after high school or had taken other post-secondary courses before taking the MFT course. Regarding their highest educational training, 10 students had completed high school, and seven held post-secondary credentials. The participants' mathematics history (see Table 2) showed that 12 indicated the highest mathematics course they had taken was high school. Most participants (82.4%) had taken a mathematics course within the last 5 years, while 17.6% had not taken a mathematics course in six or more years.

Table 2

Descriptive Statistics for Participants Demographic and Mathematics History Information

Demographic Variable	*n*	%
Gender		
Female	10	58.8
Male	7	41.2
Age		
< 21 years	7	41.2
21 - 25 years	5	29.4
26 - 30 years	1	5.9
31 - 35 years	1	5.9
> 35 years	3	17.6
First Language		
English	7	41.2
French	0	0
Other	10	58.8
Ethnicity		
Caucasian	3	17.6
Black	2	11.8
Caribbean/West Indies	3	17.6
Asian, South Asian, Southeast Asian	9	53.0
Latin American/Hispanic	0	0
Middle Eastern/Arab	0	0
Other	0	0
Educational pathway to college		
Direct from secondary school	7	41.2
Delayed	4	23.5
Incomplete post-secondary education	3	17.6
Complete post-secondary education	3	17.6
Highest educational training or degree received		
High school	10	58.8
One year community college certificate	2	11.8
Two or three year community college diploma	0	0
Bachelor's degree	5	29.4
Other – Please explain		
The highest mathematics course taken prior to MFT		
Grade 11	4	23.5
Grade 12	8	47.1
Community college	2	11.8
University, please explain	1	5.9
Non-Canadian, please explain	1	5.9
No answer	1	5.9
The number of years since taking the last mathematics course		
0 – 5	14	82.5

6 - 10	2	11.8
More than 10 years	1	5.9
Employment status		
Full time	3	17.6
Part time	7	41.2
Unemployed	4	23.5
Not in the labour force	3	17.6

Research Question One

The learning intervention (as described in Chapter Three) was designed to develop student self-awareness and self-regulation as a learner. For this question the researcher used the Online Self-regulated Learning Questionnaire (OSLQ) (Barnard, Lan, To, Patton, & Lai, 2009) to examine differences before and after the intervention in individual student's ability to self-regulate. Furthermore, surveying of participants during activities and interview responses from a select group, gave greater depth to findings about self-awareness and regulation.

The findings from the OSLQ. The researcher examined the change in students' self-regulation over the course of the study by comparing their pre- and post-intervention responses to the OSLQ. Seventeen participants completed the pre-OSLQ, and one student omitted responding to two questions. Fifteen participants completed the post-OSLQ, and two omitted responding to one question. The three omitted responses were treated with the replacement procedure outlined in the previous chapter. As the OSLQ was administered to measure a difference in results before and after the intervention, presented results reflect the data from participants (N = 15) that completed both surveys. Descriptive statistics were calculated for the pre- and post-intervention OSLQ, and means and standard deviations for each subscale and the total OSLQ are presented in Table 3.

Table 3

Descriptive Statistics for Pre- and Post-Intervention OSLQ scores (N=15)

	OSLQ Pre-Intervention		OSLQ Post-Intervention	
	Mean	SD	Mean	SD
Goal Setting	4.09	.55	4.05	.23
Environment Structuring	4.23	.59	4.30	.37
Task Strategies	3.62	.66	3.65	.41
Time Management	3.82	.68	3.67	.60
Help Seeking	3.93	.55	4.05	.49
Self- Evaluation	3.80	.47	3.80	.58
Total Self-Regulation	3.91	.32	3.94	.29

A paired-samples *t*-test was performed to examine total and subscale pre- and post-intervention differences in self-regulation. There was no significant difference in total self-regulatory learning skills of the MFT students $t(14) = .29$, $p = .77$, yet a positive *t* value indicated that self-regulatory skills of students were on average greater after the intervention. Figure 4 presents a histogram of the distribution of means for the OSLQ responses both pre- and post-intervention. As shown in Figure 4g, for mean total OSLQ score, a shift towards greater agreement can be noted for post-intervention responses. There was no statistically significant difference of the students' self-regulatory learning skills pre- and post-intervention, within the subscales. The negative *t* values for goal setting ($t(14) = -.27$, $p = .79$) and time management ($t(14) = -1.02$, $p = .32$) indicated a slight drop resulting from the intervention. Figure 4a indicated that the decrease in the mean of the goal setting post intervention might be explained by a stronger response of agree rather than strongly agree. Students may have come to the realization that they are not effective goal setters. For time management (see Figure 4d), both pre- and post-intervention distributions look similar. Most students are required to manage their time purposefully, unlike using goal setting. Positive *t* values for environment structuring ($t(14) = .37$, $p = .71$), task strategies ($t(14) = .22$, $p = .83$), and help-seeking ($t(14) = .72$, $p = .48$) indicated the mean values were higher after the intervention. For environment structuring (see Figure 4b), it seemed apparent that the distribution was shifted towards a greater agreement. The pre-intervention data for task strategies appeared to have a broader distribution than the post-intervention (see Figure 4c). From Figure 4e, the distribution of help-seeking for both pre- and post-intervention were broad, with a slight tendency towards agreement. For self-evaluation, the *t* value was zero ($t(14) = .00$, $p = 1.00$), indicating no change, which is evidenced by the distribution (see Figure 4f).

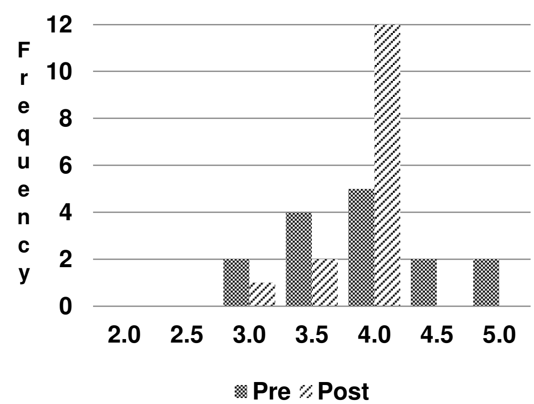


Figure 4a. Goal setting

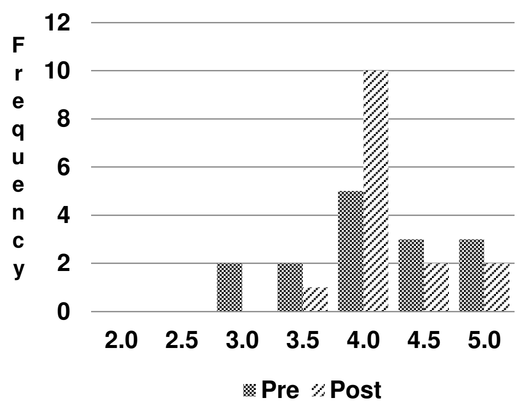


Figure 4b Environment Structuring

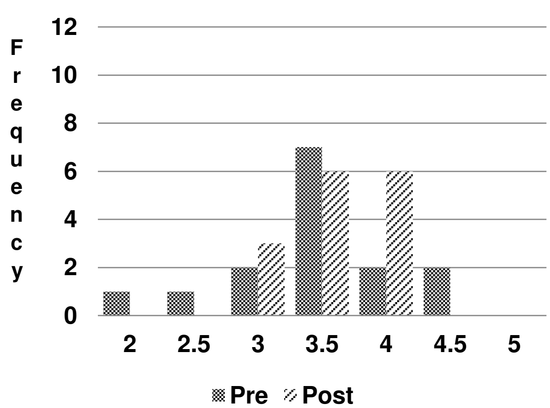


Figure 4c. Task strategies

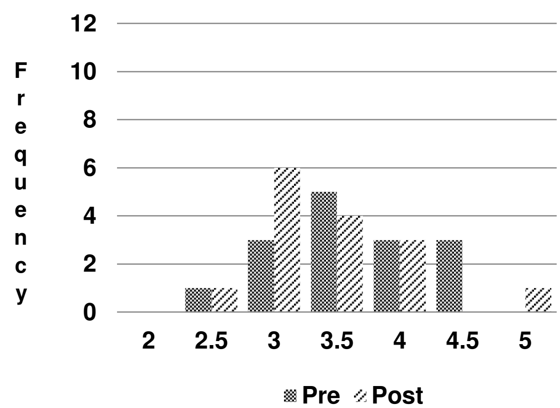


Figure 4d. Time management

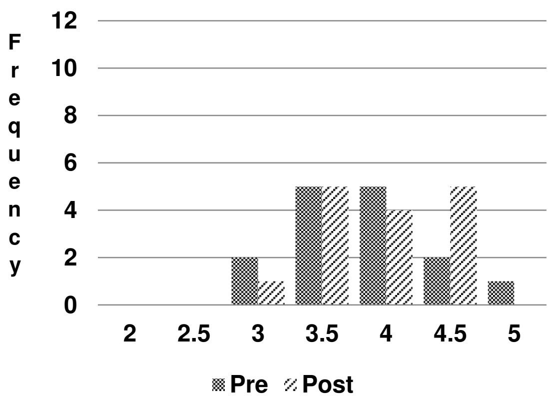


Figure 4e. Help seeking

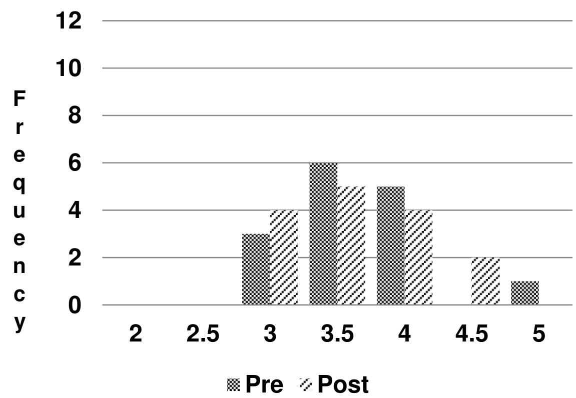


Figure 4f. Self-evaluation

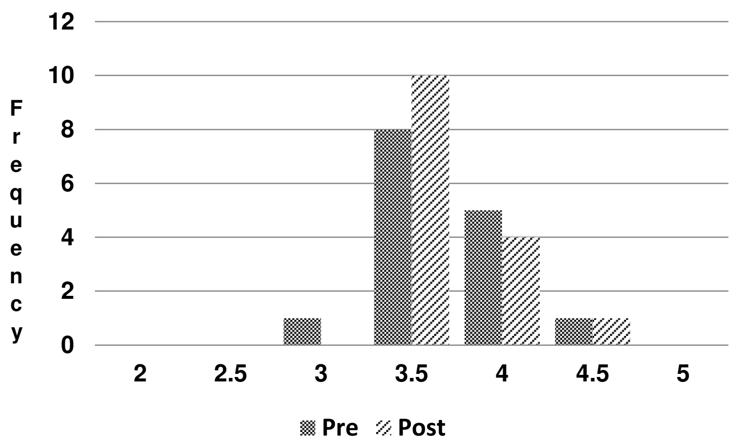


Figure 4g. Total OSLQ

Figures 4a – 4g. The distribution of the means for each of the six subscales and total OSLQ. Pre-intervention and post-intervention plotted on the same graph. The Likert scale levels on the *x*-axis are abbreviated as 2-Disagree, 3-Neutral, 4-Agree and 5-Strongly Agree. There were no responses for a Strongly Disagree level.

The findings from the student activity surveys A-D. Although quantitative analyses of data collected through the OSLQ survey did not produce statistically significant findings, qualitative analyses of students' activity surveys for each of the four activities provided insights for answering the first research question.

The instructor provided students with an example of a studynote (Activity A) and a screencast (Activity B). The studynote example contained a review of operations with fractions, followed by a solved question on complex fractions, hand-written and annotated in MS Word (see Appendix I). The screencast example gave review of metric conversions, which captured the digital ink solution on screen accompanied with the audio explanation. For their surveys, students were asked to critically examine the content of each instructor-created artefact and declare if they found it useful for their learning. During analysis, it became evident that students were starting to use the language and think in ways that could be identified as a development of self-regulation learning skills.

Students' gains from the instructor-provided studynote, and the activity in which they produced their own studynote, were exemplified in quotes about their self-awareness of how they learn and about being encouraged to develop new ways of thinking. Responses like "it makes me aware of my learning," and "it gives me a better understanding of my ability to study," demonstrated their self-awareness as mathematics learners. Related to environment structuring, students revealed that they can learn "[anytime] we want" and "whenever [we] need," specifying their understanding that the intervention allowed material to be accessible as they required it and that they could choose the pace of their learning. One student's comment that "highlighting helps me remember the parts I have to lay emphasis on," illustrated the effectiveness of this new strategy to gain clarity of "concepts of my [math] task." Several participants mentioned that a studynote would save them time as it provided "a quick review" and thus, there was "no need to read again and again other notes." Students' comments alluded to the ease with which they could receive help from the affordances provided by the intervention, in that the studynote "shows good examples which provides an easy way to remember and better understand." Students viewed this activity (A) as a way to evaluate their learning and provided comments such as, "I can use this knowledge to try to make sure I use the most of my learning strengths," and "I have [...] discovered the type of learning that best suits me." After listening to the student voice and language used in their responses, it became apparent that students connected the affordances of studynotes with a development of their personal awareness and self-regulation.

While the studynote summarized a particular mathematical solution, student responses indicated that the screencast could be used as a device to remind themselves of the previously learned mathematical processes. The screencast "made it feel real, like I was in the class again," capable of "watch[ing] the video more than once if I don't understand." Several students declared that they could use a screencast if they needed help as "the screencast just answered it all." Students described the benefit of screencasts with responses such as, "I learn better when I hear someone explain something in steps" and "it enhances the learning process with both audio and visual [modes]." Although survey responses after activity B were akin to those given for activity A, a temporal implication was evident. Students realized that a studynote was suitable for quick review and comparison of their line of reasoning, whereas, the screencasting was better suited for recreating the entire learning experience on demand. The undertone finding was that students connect the affordances of the ICT with developing self-awareness and self-regulation.

After students designed their own studynote from a choice of mathematics questions related to order of operations, fractions, and proportions, they were asked to describe three things they had learned. The same question was asked of students after creating a screencast on the mathematics topics of proportions, metric measurements, and conversions. Again, although the question did not specifically ask about self-regulation, students responded with a corresponding terminology.

Creating a studynote has helped students to be more aware: “[to] think through everything” and “[to] learn, understand, and concentrate.” They were able to structure their surroundings as they were “learn[ing] in a calm and comfortable environment” and managing their time as they “use [their] time wisely.” A few responses indicated they noted a novelty of learning mathematics: “doing my studies [in] new ways” which resulted in many comments regarding how much “faster” it was because they were “only using important info[rmation]” and did not need to “read past tons of notes.” Help seeking and self-evaluation comments related to learning “how to study properly” as the activity had been “self-explanatory for avoiding mistakes.” One student remarked that by creating a screencast, “I have felt like the teacher where I was going to lecture the students.” Furthermore, the students acknowledged that this artefact was always accessible and thus it “will help to study and understand when not in the class.” Many of the responses were similar to those given for studynotes, though, a particular difference related to the requirement for an audio explanation of mathematical thinking. Students mentioned the need for “input step by step so the user can understand” and that it was “hard to explain what I know” as they felt they were “not good at explaining clearly.” Some indicated this as a challenge, while others recognized that by screencasting their own solution, they were also able to “[realize] my mistakes.”

In the third activity (C) that spanned two 55-minute periods, students were requested to complete both a studynote and a screencast, answering questions related to unit conversions. The instructor introduced this activity as suitable for developing self-regulation, in particular for setting goals to be able to manage time for completion of work. After the activity, the students responded to three questions: (a) what they had learned about self-regulation, (b) whether they would apply these skills when studying, and (c) if they would use it for future coursework (see

Appendix Q). They commented that they had learned “how to make goals and work to[wards] them” and how to “maintain time” and “make strategies for studying.” Many made the connection between “good strategies”, “managing time,” and “less stress.” One student wrote: “[this activity] helps to [...] understand [your] learning style, it makes you see what you are capable [of] on your own, and it helps you [execute] your own style and form of solving questions.” Another suggested that, “math subject requires all the time self-regulation.”

In the final activity (D), students were given one 55-minute period to complete either a studynote or a screencast on topics of unit conversion, rounding, scientific notation, and percent. Students were asked to read and answer ten closed response questions asking them about their ability to self-regulate during the creation of this artefact (see Appendix S). The questions related to all six subscales of the OSLQ, giving them an opportunity to reflect on their ability to self-regulate on a task that required them to guide the development of their own learning resource. The feedback gathered at the completion of activity D (i.e., “When thinking about the course thus far, please comment on how effective you think you are at applying the self-regulation skills you have learned”) demonstrated perception that students were developing self-awareness and self-regulation skills during the learning intervention. This was evidenced by the following comment, given as an example: “This is not something I have been so familiar with. I haven’t given much attention to my self-regulation skills in the past. So far, I think I am getting better and more effective, [al]though I need more practice.”

The findings from the interviews. Participants were asked to explain what self-regulation meant to them in terms of their mathematics learning and how elements of the intervention may or may not have supported development of their self-regulation skills, during the interviews (see Appendix T). Only students’ responses in which they discussed the technology and made a direct reference to a self-regulation skill, were considered for research question one.

The interviewees touched on almost all of the subscales of the OSLQ in defining what self-regulation meant to them. Overall, students defined self-regulation as goal setting and using schedules to be productive in a learning environment. The environment allowed them to concentrate and self-evaluate using an organized strategy to select work that was most beneficial for their studies. Their own words demonstrated this by saying:

> "I set goals and…how much time I need to spend" [goal setting]
> "in a quiet environment" [environment structuring]
> "I learned that I learn better when there is organization." [task strategy]
> "to make those choices and leave all the rest" [task strategy]
> "I'm actually doing my work." [time management]
> "trying to regulate myself to go and proceed in the proper way" [self-evaluation]

Many of the student comments related to the learning environment created by using DyKnow technology in class. The students felt that they "could take ownership of [the work]" and that they were "focused on one thing… [because] it is in front of me," as each worked on a tablet. Participants were able to control their learning environment as well, by making the choice to sit by themselves (even with their back turned to the class and projection screen), in an effort to focus on the "teacher's voice alone." Some students made summaries during the class, by "taking notes on the side [of the screen, in the private note area]" and knew that when the notes were re-opened that "this is where I need to go." Several students stated that because they "don't need to copy all things on paper," they used their time effectively and were "able to understand" and "really pay attention," without "miss[ing] anything." Others felt in control as they were able to work at their own pace and "unpin it," meaning they did not need to follow the instructor, and "go off on my own." Responses indicated that when working outside of class some were unable to access DyKnow notes on their personal computers due to the limitations of the license.

Comments indicated that although this may have created an obstacle, some used it to their advantage. They printed notes in advance (from the LMS), added to them in class, and since they had a hard copy, read from them at opportune moments (like during a long commute). Students who believed this was to their benefit, commented that they felt they were being more organized and more efficiently managing their time. Others developed different strategies to compensate.

Responses made by students about the LMS were mostly related to the self-regulation skills of goal setting, task strategies, and time management. As the instructor's online postings were "a kind of agenda," participants were able to "prepare [themselves] for when class was going to start"; "that way I know what I need to do." The blended MFT course had multiple resources posted (e.g., links to interactive websites, worksheet generators, open educational resources, simulations, and videos). Students mentioned using sites for help-seeking and self-evaluation, such as "[I] go to answers and check what I did wrong", as "Blackboard, I am able to access it [from] anywhere." Responses such as, if "I don't know how to solve [the problem]…I just put it on Google" and "I go to the YouTube" were common, as students felt these resources were "very important for explanation." Others recognized that the "Internet, it [contains] lot of things…you have to be able to choose [among them]." Making these choices helped students to recognize when material "is related… and this is very useful," thus developing their self-evaluation skills. Others found that they were not cognisant and that they "have discovered there is a lot of good material in [the] Internet."

In addition, the instructor provided approximately 20 practice exercises from the online textbook, arranged weekly on the LMS. Student use of this affordance was found to vary in the interview responses. Some found that "the multiple postings… overwhelmed me" and thus delayed work until the final deadline, in relation to their ability to manage their time. Others used assignments to “just refresh my memory” if the mathematical concept was something they already knew, whereas “if it is something I didn’t know before, I can’t use Wiley [online textbook]…I need you to actually teach me.” Finally, it should be noted that the ubiquitous use of cell phones was common, and one student responded by saying that the “book is so heavy…[if] you want to know something, you pull up your phone”.

Research Question Two

The second research question examined how participants used the affordances provided by the learning intervention in the MFT course in relation to their age, gender, ethnicity and mathematics attitude as measured by the Mathematics and Technology Attitude Survey (MTAS) (Pierce, Stacey, & Barkatsas, 2007). The following text demonstrates the analyses that were undertaken and the ensuing findings.

The findings of number of studynotes and screencasts submitted and viewed. The first activity (A), in which students submitted a studynote on the mathematical topics of order of operations, fractions or proportions, was done over two days, of which 16/17 students (i.e., 94.1%) attended at least once. Students that did not attend these two classes did not submit an artefact. Of the 16 in attendance, six did not submit a studynote (i.e., 37.5%), ten (i.e., 62.5%) submitted at least one study note, and of that, four submitted two studynotes. In total, 14 studynotes were submitted by the MFT class. For the second activity (B), students submitted a screencast on proportion, metric measurement, or conversion, completed in one 110 minute period, of which 12/17 students (i.e., 70.6%) attended. Again, students that did not attend did not submit an artefact. Of the 12 in attendance, one student did not submit a screencast (i.e., 8.3%), 11 (i.e., 91.7%) submitted at least one screencast, and one submitted two screencasts. In total 12 screencasts were submitted by the class. The third activity (C) requested students to complete both a studynote and a screencast on two different questions related to conversion of units. Activity C was done over two days, of which all students attended at least once. Of the 17 students in attendance, five (i.e., 29.4%) did not do the assignment, three (i.e., 17.6%) completed the assignment and submitted both the studynote and screencast (of which one student submitted a studynote and two screencasts), leaving eight (i.e., 47.1%) that submitted only a studynote, and one (i.e., 5.9%) that submitted only a screencast. In total, 11 studynotes and five screencasts were submitted. For the final activity (D), students were requested to complete either a studynote or a screencast, dependent on their choice. Students submitted an artefact on the mathematical topics of conversion, rounding, scientific notation, and percent, done in one 110 minute period, of which 13/17 (i.e., 76.5%) attended. Students that did not attend did not submit an artefact. Of the 13 in attendance, two students (i.e., 15.4%) did not do the assignment, leaving nine students (i.e., 69.2%) that submitted a studynote, and two students (i.e., 15.4%) that submitted a screencast.

Table 4 presents descriptive statistics for the total number of studynotes and screencasts submitted in class during the four activities (A-D) of the learning intervention. Participants submitted 34 studynotes in total during class activities A, C, and D. Students submitted two studynotes (M = 2.00, SD = 1.17) on average, with three (the highest number) submitted by six students. Two students (11.8%) did not submit any studynotes, even though they attended at least one of the related classes. Students submitted 19 screencasts in total during class activities B-D. On average students submitted one screencast (M = 1.12, SD = 1.17). Four participants did not submit any screencasts, although all were in attendance at least once, and one student submitted five screencasts in total. Participants submitted 54 artefacts in total, with an average per student of 3.18, SD = 1.74, for the intervention period. The majority of students submitted between one to four artefacts (82.2%, n = 14), however, one student (5.9%) submitted seven artefacts in total during the four activities. All students submitted at least one artefact, whether it was a studynote or a screencast.

Table 4

Number of Studynotes and Screencasts Submitted During the Activities A-D (N = 17)

	None	1 Artefact	2 Artefacts	3 Artefacts	4 Artefacts	5 Artefacts
Studynote (# of students)	2	4	4	6	1	0
Screencast (# of students)	4	10	2	0	0	1

The instructor annotated the student submissions, then posted the artefacts to the RESEARCH content area of the course site. A separate file was created (labelled Activity A-D, respectively), and all artefacts were made available for students to view at their convenience. A tracking feature of the LMS was employed to count the number of times (views) students opened each of the four files. The researcher was unable to know which of the artefacts within the file the student viewed, for how long, nor whether the content was downloaded, due to limitations of the tracking software. Table 5 presents descriptive statistics of the number of times students logged into the LMS and viewed the four files generated by each of activities A-D. The students opened the files and viewed their content 465 times in total, with 27 average views per student (M = 27.35, SD = 18.76). Participants viewed the postings at least four times, while one student did it 70 times in the 31 days of the tracking.

Table 5

Descriptive Statistics of Participant Views of Artefacts for Each of the Four Activities (N = 17)

Activity	# of artefacts in a folder	Number of views (in 31 days)	Mean number of views per student	Extreme values Range of views per activity
Activity A- Student designed studynotes	14 studynotes	208	Mean = 12.24, SD = 8.26	Min = 4 Max = 35 R = 29
Activity B - Student designed screencasts	12 screencasts	153	Mean = 9.00, SD = 6.15	Min = 0 Max = 22 R = 22
Activity C - Student designed studynotes and screencasts	11 studynotes 5 screencasts	66	Mean = 3.88, SD = 4.14	Min = 0 Max = 14 R = 14
Activity D - Student designed studynotes or screencasts	9 studynotes 2 screencasts	38	Mean = 2.24, SD = 2.75	Min = 0 Max = 9 R = 9
Total	34 studynotes 19 screencasts	465	Mean = 27.35, SD = 18.76	Min = 4 Max = 70 R = 66

A Pearson bivariate correlation test was used to gain insight into how $N = 17$ participants used the artefacts provided by their fellow classmates in Activities A-D. The number of views by students of the first activity (A) folder had a significant strong association to their viewing of the second activity (B) folder ($r = .87$, $p < .001$) and third activity (C) folder, ($r = .54$, $p = .02$), but the correlation was weaker and not statistically significant for the fourth activity (D) folder ($r = .46$, $p = .06$). For Activity D, the artefacts were submitted, annotated, and posted on the day before the test, which could be a contributing factor to their decreased utilization. Correlations were positive and strong (Cohen, 1988; George & Mallery, 2014), with the exception of the case mentioned above. The results demonstrated that students were using the artefacts supplied by their classmates, and continued to do so as new artefacts became available.

Further, correlations were computed for the number of views for each of the activities (A-D) and total number of either studynotes or screencasts submitted (see Table 6). There was no significant association, indicating that the number of times students viewed the artefacts was not dependent on how many they had personally submitted. They were not simply opening the files posted on the LMS to view their own work, but also that of other students.

Table 6

Pearson Correlation for Studynotes or Screencasts Submitted Related to Participants' Views (N=17)

Pearson Correlation (N = 17)	Total # of Studynotes Submitted	Total # of Screencasts Submitted
Views of Activity A	r = -.13, p = .62	r = .03, p = .91
Views of Activity B	r = .04, p = .87	r = -.04, p = .89
Views of Activity C	r = .03, p = .92	r = -.14, p = .59
Views of Activity D	r = -.02, p = .94	r = -.09, p = .74

The LMS tracking mode also allowed the researcher to gain information about student usage. Of importance to this study was the summary of number of times students opened files on a daily basis for each activity. The tracking confirmed that all students opened the files containing studynotes and screencasts at least once, regardless of whether they had attended the class or submitted the required artefact. Figure 5 summarizes the number of times the 17 students opened the activity folders (A-D) on a daily basis.

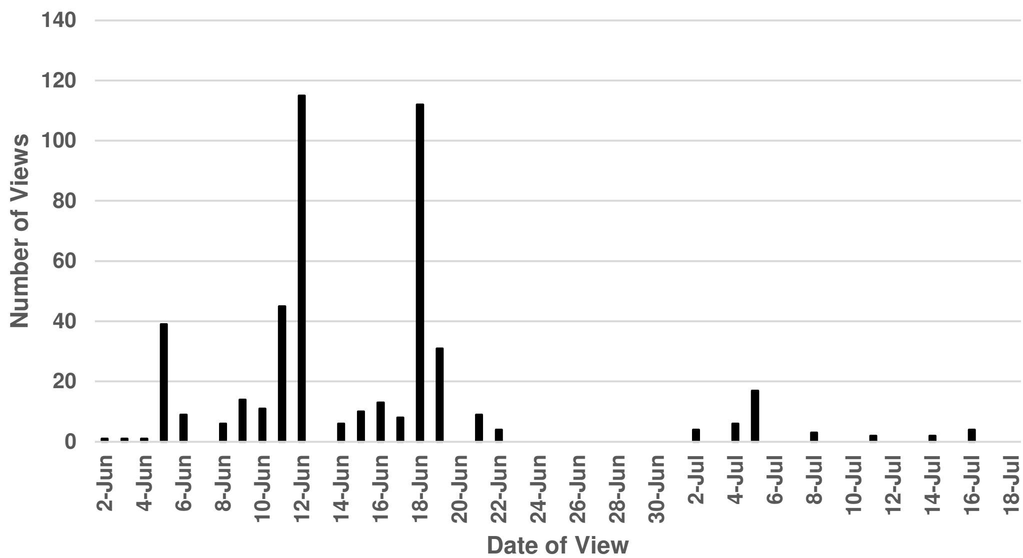


Figure 5. LMS tracking of student views by date for activities A – D. A tool embedded within the software recorded the number of times each of the four activity files containing student artefacts (studynotes and screencasts) were viewed within the course organization site.

There were two peak times when students opened the activity folders (see Figure 5), June 11/12 and June 18/19. These dates corresponded to the day before and the day of a quiz, and the day before and the day of a test, and represent approximately 50% of the total number of views. To investigate the significance of this just-in-time (JIT) viewing further, the number of views were averaged for the two days (June 11/12) and a new variable identified as “JIT views for quiz”. Similarly, the number of views were averaged for June 18/19, and a new variable identified as “JIT views for test.”

Activities A and B were posted before the quiz on June 12. Analysis revealed statistically significant strong positive correlations between JIT views for the quiz and the number of views for activity A ($r = .55$, $p = .02$) and activity B ($r = .62$, $p = .01$), for $N = 17$. All four activities were posted before the test on June 19, and statistically significant strong correlations were found between JIT views for the test and number of views for activity A, ($r = .63$, $p = .01$), activity B, (r = .60, p = .01), activity C, (r = .79, p < .001), and activity D, (r = .86, p < .001). Although each of the activities were tracked for the 31 days following posting, there was a significant association for participants viewing activities either the day before, or the day of, an assessment.

The findings of how the demographic factors related to creating and viewing a studynote or screencast. Only demographic variables of age, gender, and ethnicity were chosen for inferential analysis (see Table 2), to answer the second research question. A non-parametric test, the Mann-Whitney U was used to compare the total number of studynotes and the total number of screencasts submitted by the two age groups: (a) participants 25 years or younger, and (b) participants older than 25 years. This statistical test was used to compare participants based on reported gender (M or F) and also to compare participants grouped as Asian and other, as more than half of students self-identified as having an Asian ethnicity. No statistical differences existed in the number of studynotes or screencasts produced by students based on the demographic variables of age, gender, or ethnicity defined this way (see Tables 7 and 8).

Table 7

Total Number of Studynotes Submitted

Demographics Category	Number of Students	Mean rank	Mann-Whitney U (two tailed)
25 years or younger	12	8.71	U = 26.50, Z = -.38, p = .70
Older than 25 years	5	9.70	
Female	10	10.85	U = 16.50, Z = -1.87, p = .06
Male	7	6.36	
Asian	9	8.06	U = 27.50, Z = -.85, p = .40
Other	8	10.06	

Table 8

Total Number of Screencasts Submitted

Demographics Category	Number of Students	Mean rank	Mann-Whitney U (two tailed)
25 years or younger	12	9.33	$U = 26.00, Z = -.48, p = .63$
Older than 25 years	5	8.20	
Female	10	9.30	$U = 32.00, Z = -.33, p = .74$
Male	7	8.57	
Asian	9	10.22	$U = 25.00, Z = -1.20, p = .23$
Other	8	7.63	

From the Pearson correlation findings above, the greatest number of views of the activity files in the LMS occurred from JIT (just-in-time; see explanation above) viewing in preparation for assessments. Table 9 and Table 10 present the results of group comparisons using the non-parametric test Mann-Whitney U, based on the number of JIT quiz and JIT test viewings. The findings for this test show that the students who were older than 25 years viewed the artefacts posted in the activity files of the LMS before the quiz statistically significantly more times than did the students who were at most 25 years old. However, none of the differences were significant for JIT viewing for the test.

Table 9

Mann-Whitney Test for Just-in-Time (JIT) Quiz Views Related to Demographic Factors

JIT Quiz Viewing	Number of Students	Mean Rank	Mann-Whitney U (two tailed)
Age			
25 Years or Younger	12	7.33	$U = 10.00, Z = -2.12, p = .03$
Older than 25 years	5	13.00	
Gender			
Female	10	9.95	$U = 25.50, Z = -.93, p = .35$
Male	7	7.64	
Ethnicity			
Asian	9	7.28	$U = 20.50, Z = -1.50, p = .13$
Other	8	10.94	

Table 10

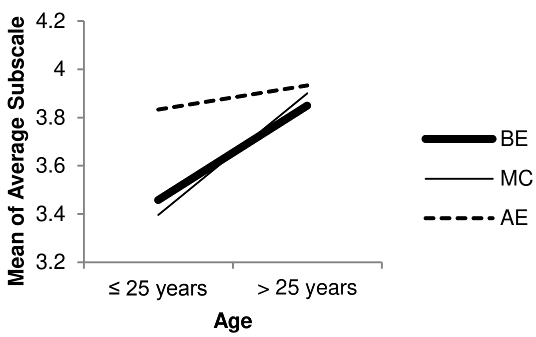
Mann-Whitney Test for Just-in-Time (JIT) Test Views Related to Demographic Factors

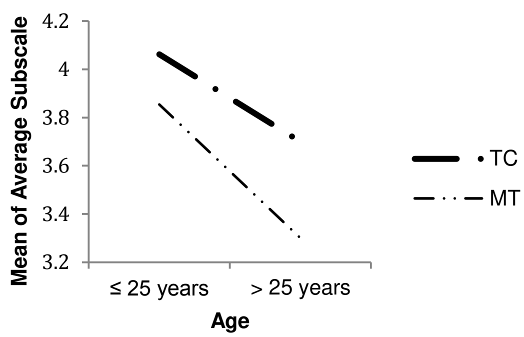
JIT Test Viewing	Number of Students	Mean rank	Mann-Whitney U (two tailed)
Age			
25 Years or Younger	12	8.75	$U = 27.00$, $Z = -.32$, $p = .80$
Older than 25 years	5	9.60	
Gender			
Female	10	10.15	$U = 23.50$, $Z = -1.14$, $p = .25$
Male	7	7.36	
Ethnicity			
Asian	9	9.83	$U = 28.50$, $Z = -.73$, $p = .46$
Other	8	8.06	

The findings of how the responses of the MTAS related to creating and viewing a studynote or screencast. The second part of this research question was addressed by examining student response to the Mathematics Technology Attitude Scale (MTAS) (Pierce, Stacey, & Barkatsas, 2007). The MTAS survey was administered before the intervention to obtain a background assessment of students' attitudes towards mathematics, technology, and learning mathematics using technology. For behavioural engagement, a median of 15 showed that student learning behaviour was moderately high (using a range 4-20). A highly positive attitude for the technology confidence subscale, a median of 17, demonstrated that participants were self-assured in using technology. The lowest median found was 14 and it related to mathematics confidence, a reflection of the students' assertion of their ability to deal with difficulties and their assurance they could achieve good results. A median of 16 for affective engagement, indicated that students felt they were moderately highly engaged, while a median of 15 showed that participants had a moderately high attitude toward learning mathematics using technology.

The mean of each MTAS subscale was recalculated for each student, to carry out further statistical analysis. An independent-samples *t*-test was conducted to compare the average of the means of each of the MTAS subscales to age in two conditions, students aged 25 years or younger to those older than 25 years. No statistically significant differences were found, but when the averages of the means were plotted for each of the two age groups, trends were noted (see Figure 6).

For the subscales of behavioural engagement (BE), mathematics confidence (MC), and affective engagement (AE), the average of the means for students 25 years or younger were lower than those over 25 years (Figure 6a). For the subscales of confidence with technology (TC) and attitude towards learning mathematics with technology (MT), the average of the means were higher for students 25 years or younger (see Figure 6b).





Figures 6a-6b. Means of average MTAS subscale versus age. Subscales of the MTAS are as follows: Behavioural Engagement (BE), Mathematics Confidence (MC), and Affective Engagement (AE). Technology Confidence (TC), and Learning Mathematics with Technology (MT). Participants' age is represented as "at most 25 years old" and "older than 25 years."

Further quantitative analysis regarding student attitude to using technology for learning mathematics was not undertaken.

The findings from the activity surveys related to creating a studynote or screencast. Two questions from the activity surveys related to students' attitude regarding the affordances of the intervention. The first question in the activity A-B surveys related to whether students felt they would use a studynote or screencast in future coursework. Of the 13 students who responded to the studynote survey, 12 said they would, while one was unsure. Responses to the open ended question revealed that students found that the studynote made their learning easier and “it [was the] best way to learn difficult problems.” Of the nine students who responded to the screencast survey, all agreed they would use screencasts for future coursework. Their responses to the open ended question indicated that the screencast “helps others to understand” where mistakes are made, for example one student wrote: “I watch my screencast because by this I can know about my previous mistakes.” Students expressed their attitude towards these learning methods by stating “I think I will use this method of studying from now on” and “I always watch screencasts.” Participants indicated their confidence in learning mathematics using technology, such as in one student’s response: “this screencast is really helpful so I will watch it during my [preparations for] exams, tests, or quiz.”

The second question (in Activity A – B) related to whether students felt they would make a studynote or screencast in future coursework. Of the 13 students who responded to the studynote survey, 12 said they would, one was unsure. Students agreed that they would make studynotes, because “it really helps me study,” and noted its benefit “as material to consult or help others.” Of the nine students who responded to the screencast survey, six agreed they would make a screencast in future coursework, two felt they would not, and one was unsure. Responses regarding their making further screencasts varied, as some felt “too shy to speak up”, and others stated that they would “rather help someone face to face.” Some felt they would make screencasts “for more practice [because] it’s a lot of fun” while others found a screencast as an “innovated method to learn more [mathematics].”

The findings from the interviews related to creating a studynote or screencast. Further insights were gained from the semi-structured interviews with students. Student answers were categorized using the MTAS subscales, when questioned whether they preferred to make or read/watch, a studynote or a screencast. Answers suggested participant affective engagement as they recognized the benefit of "when I teach someone…it increase[s] my knowledge too." Related to mathematics confidence, some students felt that if they did more artefacts, "that will make me feel more confident" because "in this way, I am learning as well, or I am reviewing what I learnt before." Others who "[felt] a little bit insecure or not confident" preferred to "watch [a] friend's screencast…because I am not sure [if mine]… is going to be true or right…I think hers is going to be better." Some found doing the screencast in class "can be disturbing [to others]" and because "I can be the shy type of person… I prefer studynote," while others mentioned that they "hate being recorded, that's why I picked studynotes," in relation to compatibility of the technology with one's personality. Some said the screencast was less convenient to work with, because "once you make a mistake you have to…start over again," and for others "I can't remember the things I have said." Learning mathematics using these different technologies was not the same, because "I like to watch other peoples' screencast, 'cause it is more explanatory, knowing the magic going on in the equation…; a studynote might not be as explanatory." Others preferred doing the screencasts themselves because "when we hear our own voice, we are able to understand much more." Students changed their attitude towards mathematics and affective engagement, since "before [this class], I didn't like to do maths, but now I like to do math too, because of the screencasting." Creation of a screencast required some to "think for two people" and to "show the step-by-step [solutions] …to make it easy for another person to understand." Students realized that by "doing [an artefact] for another person" their habitual method of work that was "direct" had to be modified, resulting in "pay[ing] more attention" and "double check[ing]." Finally, a few students commented that they "didn't only learn math […]; I learned other things outside of math, which is what I think the learning experience in class should be."

Research Question Three

The learning intervention (as described in Chapter Three) was designed to provide multiple learning experiences for different types of learners. The third research question examined demographics, attitude, self-regulation, and types of artefacts submitted as they related to student learning style. Only the relations to the active or reflective learning styles (as obtained through the ILS) were investigated, as the intervention provided multiple affordances for students. The impact of learning style was examined in four parts: (a) demographic factors of age, gender, and ethnicity, (b) attitude, (c) potential changes in self-regulation, and (d) impact on number of artefacts submitted.

The findings of the ILS on active or reflective learning styles. For the ILS, of the 17 participants, nine (52.9%) were categorized as having reflective learning style and eight (47.1%), an active learning style (see Figure 7) with a median of -1 (Range -7 to +7). None of the students were strongly reflective, three (17.6%) were moderately reflective (scored -7 to -5) and six (35.3%) were mildly reflective (scored -3 to -1). Six students (35.3%) were mildly active (scored 1 to 3), two (11.8%) were moderately active (scored 5 to 7), and none were strongly active. The largest group fell within the mild category for both active and reflective learning styles (n = 12, 70.6%). According to the scoring sheet provided by Richard Felder (Felder & Soloman, n.d.) for this study, most participants were principally well-balanced, demonstrating only a mild preference for either the active or reflective dimension.

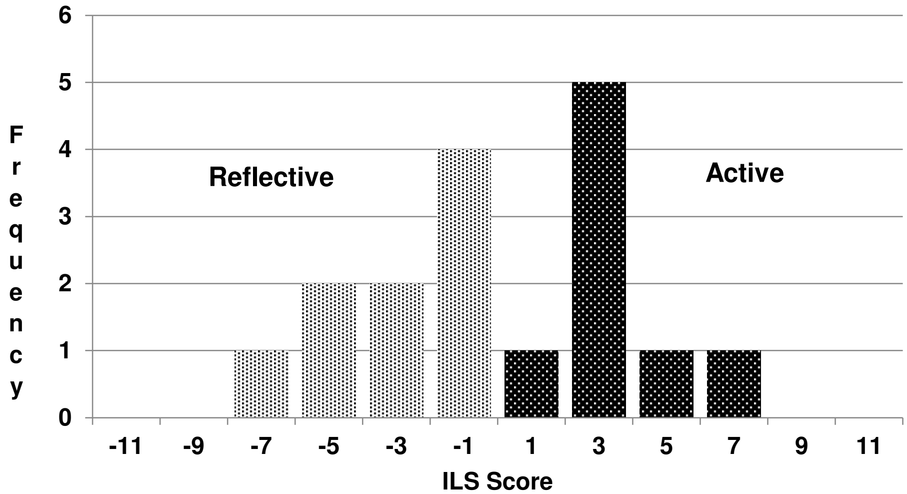


Figure 7. Active and reflective ILS score. Number of students scoring in each of the active or reflective mild, moderate, or strong categories.

The findings of the demographic factors as related to active or reflective learning styles. In order to verify normalcy of distribution, active and reflective learning styles were considered in 8 categories (-7, -5, -3, -1, 1, 3, 5, 7). As explained in Chapter Three, two age groups were considered: participants up to 25 years old, and older than 25 years. A Shapiro-Wilk's test (Shapiro & Wilk, 1965) gave a normal distribution for these two age groups, W= .18 and W=.31 respectively. An independent-samples t-test was conducted to compare active-reflective learning styles by age in two conditions. There was a significant difference ($t(14.95)$ = 2.72, p = 0.02) in the learning styles scores for participants of age 25 years or younger (M = 1.17, SD = 4.04) and participants older than 25 (M = -2.60, SD = 1.67); older students preferred to use a reflective learning style to process information. There was no significant difference ($t(13.91)$ = .96, p = .36) in learning style scores for female participants (M = .80, SD = 4.25) and male participants (M = -1.00, SD = 3.65). An independent-samples t-test was conducted to compare learning styles to ethnicity defined in two conditions: (a) those that self-identified as Asian and (b) those that did not. A Shapiro-Wilk's test gave a normal distribution for these two ethnic groupings, W= .81 and W=.42, respectively. There was a significant difference ($t(13.94) = 2.31$, $p = 0.04$) in learning styles scores for participants that self-identified as Asian ($M = 1.89$, $SD = 3.18$) and other ($M = -2.00$, $SD = 3.70$); students that self-identified as Asian preferred to use an active learning style.

The findings of the MTAS related to active or reflective learning styles. For each value on the reflective and active scale (-7, -5, -3, -1, 1, 3, 5, and 7), student responses were averaged for the sum of the subscales of the MTAS survey (mathematics confidence (MC), technology confidence (TC), learning mathematics with technology (MT), affective engagement (AE) and behavioural engagement (BE)). A scatter plot graph was produced for each subscale, accompanied with the line of best fit (see Figure 8). Reflective learners (presented on a negative portion of the scale) tended to have a lower behavioural engagement and attitude toward using technology to learn mathematics than active learners (presented on a positive portion of the scale). However, they had a higher mathematics confidence than did active learners. Technology confidence and affective engagement appeared to be about the same.

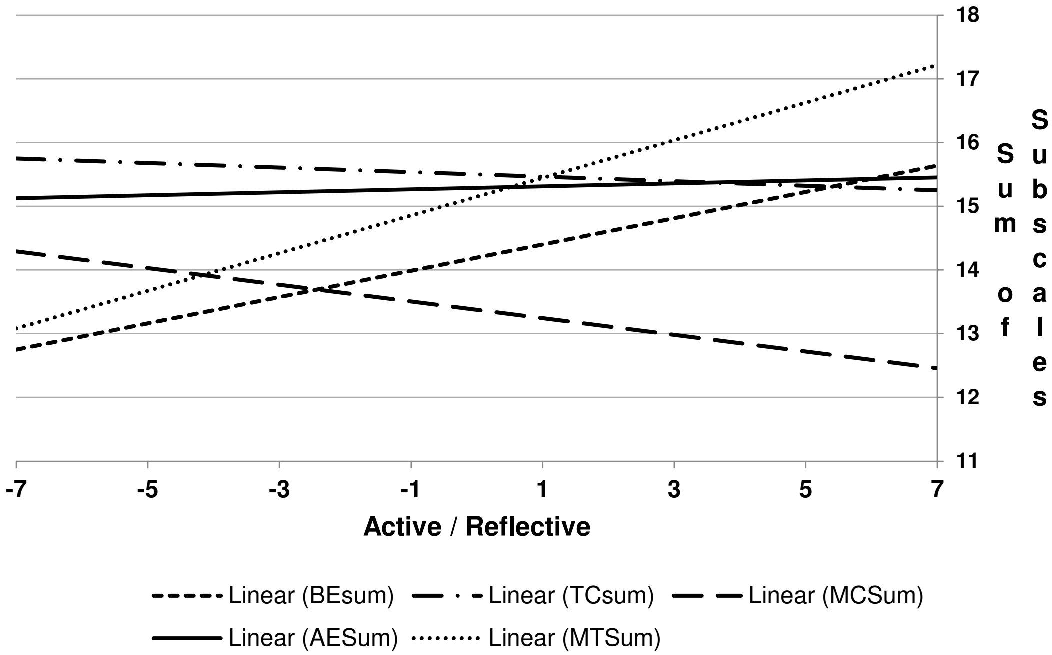


Figure 8. Lines of best fit of the sums of the MTAS subscales related to the active or reflective learning styles. MTAS subscales are Behavioural Engagement (BE), Technology Confidence (TC), Mathematics Confidence (MC), Affective Engagement (AE), and Learning Mathematics with Technology (MT).

The findings of the OSLQ (pre- and post-intervention) related to active or reflective learning styles. The mean OSLQ score was considered for both the pre- and post-intervention surveys for each student. A difference was calculated by taking the total OSLQ mean score for the post-intervention survey and subtracting the mean score for the pre-intervention survey. These differences were graphed on a scatter plot against the active or reflective learning style score for individual students (see Figure 9). Based on a line-of-best-fit, the trend was that active learners seemed to have benefited more from the learning intervention, as measured by their positive increase in self-regulation. However, only 17% of variability in the self-regulation was related to the active-reflective score.

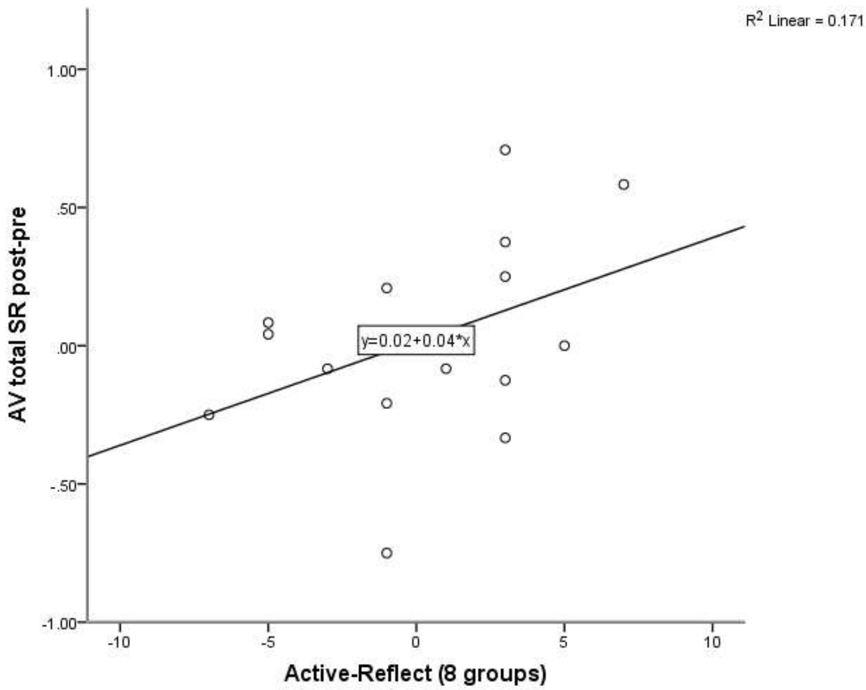


Figure 9. Scatterplot of OSLQ differences for active and reflective learning styles. The difference in the OSLQ mean (post- subtract pre-intervention) for each student was plotted against their score in the active or reflective dimension.

The findings of number of studynotes and screencasts submitted as related to active or reflective learning styles. Artefacts submitted to the online course management system during the four in-class activities included 34 studynotes and 19 screencasts. There was a significant difference ($t(16) = 3.015$, $p = 0.008$) in average number of studynotes ($M = 0.59$, $SD = .34$) and average number of screencasts ($M = 0.31$, $SD = 0.28$) per activity. The students completed significantly more studynotes, thus taking a more reflective personal learning approach. These findings may not be generalizable to other study conditions. Possible reasons why students preferred studynotes over screencasts may be that creating studynotes is easier and requires less time commitment. Further, in a screencast, a student must explain their mathematical thinking which may be difficult for students to articulate, particularly in a non-dominant language.

The findings from the activity surveys as related to active or reflective learning styles. Participants were asked whether doing this activity related to their personal learning style, in the first activity where students designed their own studynote. Findings indicated that 12/13 (92.3%) agreed that this indeed was the case and only one student did not agree. Answers to the open-ended journal question were categorized by the student's learning style. Students with an active learning style responded that they felt more organized, as "I have the important thing edited in my studynote" and it was "much more clear." Many related the studynote to being "easier" and "a lot faster to study with," as it "cuts down on time." Finally, the comment that "writing info[mation] about coursework gives me a better understanding" indicated the active learners' preference for doing something quickly to increase understanding and organize their work. Reflective learners also agreed that the studynote helped them to "state information clearly," however more comments were related to its impact on "concentration" with a mention of "I think through everything" and "I can observe model questions." One reflective learner's comment of "people who like math…[are] not…talkative or outgoing," provided a personal account. In general, I noticed that reflective learners used words such as 'thinking', 'consulting', 'concentrating', rather than the words used by active learners, such as 'doing', 'writing', and 'editing'.

Students were asked the same questions in the second activity, where students created their own screencasts. Findings indicated that 7/9 (77.8%) students agreed that this activity was related to their learning style, and two were unsure (22.2%). Answers to the open-ended question indicated that students with active learning styles were attracted by the novelty of this activity:

some examples, "I like to learn new techniques", "new ways of studying", "[this is] an innovative method to learn more", and "I have never used this method before but I think I will implement this." Others mentioned that it was "hard to explain what I know in a form of a screencast for someone else to hear." This was also voiced by participants with a reflective learning style, one of whom wrote "I am not good at explaining clearly." Further, reflective learners commented that they were "too shy to speak up" and "not a fast thinker," but they recognized the value of doing screencasts to "assist others" and "help others understand." In general, active learners appreciated doing the screencast activity because it was a new technique, whereas reflective learners thought it provided a better way to help others.

The findings from the interviews as related to active or reflective learning styles. Criteria for choice of participants for interview was to achieve representation (where possible) from each of the eight levels of active and reflective learning styles (-7 to 7), and to invite students who participated in the majority of the activities. Once both of these criteria were met, a variation of age and gender were utilized to have a representative student sample. Responses were coded (as explained in Chapter Three) and only those that spoke of the affordances of the studynote and screencast activities in relation to their learning styles are presented in this section. Some examples of student responses of which they preferred doing, studynote or screencast, compared to which they watched, and why:

> ***Scored moderate on the active scale (7a)***
> I liked to do screencasting better because it is…very enjoyable…It is written…[and] we are going to record our own voice. So by doing screencasting, also we are speaking how we have to do the sum, step-by-step…and it is helpful. Then couple of days passed, I forgot how…to do this sum. I watch[ed] the screencast…I hear it again. Because I have explained [it before]… it is easy for me to learn again…so that is why I think it is interesting. I watched other people's screencasts, because…[those] screencasts…are also very helpful.

Scored moderate on the active scale (a different participant, 5a)
I think screencasting is better than studynote because studynotes are just written… whereas in screencasting we have audio. We hear our own voice, we hear that sound again and again…[and] we are able to understand much more. I prefer to do [it] myself, in my way, [to check if] we have made any mistake…[therefore] increasing your level of math. But when I am not able to solve it, then I prefer to listen, something or someone who has done it.

Scored mild on the active scale (3a)
For the studynote…you already have the equation solved, it is just you writing it. When you make a mistake, you can just clear it and start over again. But for the screencast, when you make a mistake, you have to clean it and start talking over again and over again and over again. At times I can't remember the things I have said, the things I should say and the things I shouldn't say. But I like to watch other peoples' screencast, [be]cause it is more explanatory. When it is coming from my mate, I don't take it seriously. But when it is coming from like an instructor, I take it more seriously.

Scored mild on the reflective scale (1r)
Studynotes…I like it better…because I can look at it, and I can figure out how you did it…visualizing. The teacher doing the screencasting…it is spoken in a way for me to understand. Nobody really put the effort into explaining it the way it should be. I think it had a lot to do with…just the time factor, a lot of them were rushed, [be]cause we only had a certain amount of time. If I had to do… [a screencast] as a project for myself… I think I would put more, I don't want to use the word effort, but I would try to make it more understandable.

Scored mild on the reflective scale (a different participant, 3r)
I picked [doing] studynotes. I don't like being recorded. I always did them first on paper, and then I would organize it on the screen, and…only put what was useful [onto the studynote]. I have used both… all the time. I've used screencasts…I was able to listen and watch what they were doing, versus how I am doing it, and then I was able to perfect what I was doing. If I was doing something wrong or doing it different, and there way was a more efficient way, I was able to change it.

Scored moderate on the reflective scale (5r)
Screencast I have not done this one. I don't know how can I use, and I am shy to ask… I don't like my voice. Studynote, I… wrote down on the screen, and then take a picture, instead of…record. So I have to explain the theory because I have to think… in another person. She doesn't think…the same as I think. I can go directly to the result. But maybe she cannot understand what I am doing. So I have to put [the] arrow…I am multiplying, I am subtracting, I am adding, so step-by-step. I will be more detailed. For me, I didn't think this way. If I am sure that I am doing [it right], I go directly. But in this way, I am learning as well, or I am reviewing what I learnt before.

This chapter described the integration of quantitative data (ILS, demographic, MTAS, OSLQ, surveys, attendance, number of studynotes submitted, number of screencasts submitted, and viewing of artefacts on the LMS) and qualitative data (survey and semi-structured interview responses) to answer the three research questions. The next chapter will interpret these findings to provide a framework for the affordances of this learning intervention, implications and limitations of the study, and recommendations for future work.

CHAPTER FIVE

DISCUSSION AND CONCLUSION

The study used a mixed-methods research design to examine how the affordances of the technologically-rich learning intervention could be utilized to increase both student self-awareness and self-regulation of their learning in a first-year community college foundational mathematics course. The study was quantitative-dominant (Johnson et al., 2007), using the qualitative data to complement the quantitative (Greene, Caracelli, & Grahman, 1989), and to enhance significance of findings (Collins, Onwuegbuzie, & Sutton, 2006), especially in view of the limitations of this study, such as the small sample size. The participants were taking a non-credit Mathematics Foundations for Technology (MFT) course in preparation for subsequent first and second year mathematics courses.

This final chapter integrates the key outcomes of the research study with the current literature. It concludes with the implications and limitations of the study, as well as recommendations for foundational mathematics practice and suggestions for potential research.

Summary of Findings

This study was inspired by calls from many authors (e.g., Howe & Strauss, 2000; Prensky, 2001a; 2001b; Oblinger & Oblinger, 2005; Tapscott, 1998; 2008) who recommended that pedagogy used for teaching in post-secondary institutions must evolve to meet the technological needs of students. The learning intervention designed used pen-based tablet PC computing, scaffolded learning materials delivered through DyKnow software and the learning management system (LMS), survey instruments, and student artefacts of studynotes and screencasts. Findings as they related to the three research questions, *How do the affordances provided by the learning intervention that are perceived to support metacognition (i.e., self-*

awareness and self-regulation) enhance self-regulation of students in a foundational mathematics college course?; How do student demographic factors (e.g., age, gender,and ethnicity) and attitude towards learning mathematics with technology relate to their utilization of the affordances of the learning intervention in a foundational mathematics course?; and *How does learning style, based on the active or reflective dimension, relate to student demographics, attitude toward mathematics, self-regulation, and choice of artefact in the learning intervention designed for students in foundational mathematics courses?* are presented first, followed by a summary of the affordances provided by the learning intervention.

The impact of affordances of the learning intervention on the development of participant self-regulation skill. Self-regulation skills can be learned (Iran-Nejad, 1990), and students can benefit from being instructed in them (e.g., Zimmerman, 2008). Previous research has demonstrated that for underprepared students in developmental mathematics courses, self-regulation training (Ley & Young, 2001; Young & Ley, 2001) and the use of online tools to self-monitor homework can enhance skill (Bembenutty, 2009; Ramdass & Zimmerman, 2011). For this study, the students were provided a similar opportunity through the access to instructor-provided scaffolded class notes and through the creation of student artefacts (studynotes and screencasts). Differences in ability to self-regulate were measured by comparing the mean values of the total and each of the subscales for the 15 participants who completed both the pre- and the post-intervention Online Self-regulated Learning Questionnaires (OSLQ) (Barnard, Lan, To, Paton, & Lai, 2009). Using a paired-samples *t*-test, no significant difference was found for either the total or each of the individual subscales. This non-significant finding is similar to that of Barnard-Brak, Paton, and Lan (2010) and "may reflect a slower or no development at all of self-regulatory skills" (p. 67). As the Barnard-Brak et al.'s study took place over one semester (18 weeks) without a significant measurable change, it can be postulated that this six-week intervention may not be of sufficient duration for the self-regulation skills to be realized and reported by students. The complementarity nature of this mixed-method research allowed for a richer interpretation, thus, each measurement parameter of self-regulation will be considered separately.

As described above, the paired-samples *t*-test value for goal setting of $t(14) = -.27$, $p = .79$ was non-significant and also negative, suggesting that students' setting of goals, personal expectations, and high standards might have slightly diminished over the intervention. As presented in the histogram (see Figure 4a), this finding could indicate that after training and practice in goal setting, students had a better understanding of the subscale and became more self-aware and thus critical of their goal-setting skills. A positive task strategies value ($t(14) = .22$, $p = .83$), and a slight positive shift in the histogram (Figure 3c) suggested that participants agreed more with ideas of making review notes, preparing for class, and working extra problems. Few studies have been found in the literature that compare pre- and post-intervention means for goal-setting and task strategies in online environments. In the "messy world of classroom learning" (Boekaerts & Corno, 2005, p. 199), many theorists restrict their self-regulation focus to academic achievement. Lowanto, Santoso, Lowanto, and Goodridge (2014) compared the OSLQ features for higher and lower performing students, with that of the LMS tracking data of number of times materials were accessed. They found that regardless of student self-report, tracking data showed that higher performing students "accessed all course materials significantly more frequently" (p. 16). The literature demonstrated that students may report their behaviours inaccurately (Bol & Hacker, 2001; Bol, Hacker, O'Shea, & Allen, 2005) or may be unable to recognize their deficiencies (Bol, Campbell, Perez, & Yen, 2016). For this study, the combination of activity surveys and the semi-structured interviews provided a significance enhancement (Collins, Onwuegbuzie, & Sutton, 2006). Evidence from student learning transcripts suggested that self-regulated learning is “a developing process that came into play more or less, depending on the situation” (Boekaerts & Corno, 2005, p. 208). From the learning intervention, Activities A (studynote) and B (screencast) were structured in the same way, yet opened two distinct learning opportunities. Students viewed an instructor-provided artefact, and made observations of its match with their learning style, then created a similar artefact, and commented on the application experience, by replying to open-ended questions. From the survey analysis presented in Chapter Four, it is evident that students observing an instructor-provided artefact reflected on its task strategies affordance, for example “highlighting helps me remember the parts I have to lay emphasis on.” Most comments related to ways in which the artefact could benefit their learning. On the other hand, after students had created their own artefact, responses related to how they had set goals for completion, managed time, and evaluated work. In summary, as users, the students focused on how they could use the instructor-provided artefact for their learning needs, whereas, when creating their own, they utilized self-regulation skills.

Environment structuring and time management are skills required by developmental mathematics students so that they are able to benefit from their learning experience. From the paired-samples *t*-test, there was no significant difference before and after the intervention, but environment structuring ($t(14) = .37$, $p = .71$) was positive. From the histogram (see Figure 4b), the trend demonstrated a shift towards a greater agreement with items such as choosing a time and location where studying can occur comfortably, efficiently, and without much distraction. There was little in the literature that related to students structuring their own environment in relation to developmental mathematics courses taught with the enhanced use of ICT. Teaching in blended mode with the use of ICT affords students the option of learning anywhere and anytime, as they prefer. However, instructors question whether all of the resources offered are actually being used by students. From the interviews and activity surveys, students commented on this flexibility and that they could then choose to learn in a "calm and comfortable environment." Some mentioned a preference for doing a studynote over a screencast, as they felt the audio recording might have disturbed neighbouring students (note that these activities took part during class time). Tracking of student utilization of the affordances provided by the learning intervention gave an answer to this question for foundational mathematics students. Studynote and screencast artefacts from the four activities were posted in individual files in the LMS. Research folders A-D had 34 studynotes and 19 screencasts (see Table 4), and in total, these folders were opened 465 times within 31 days of posting. Further, students were using these artefacts to suit their studying needs, as peak activity occurred either the day before or the day of a quiz or test (see Figure 5). Having all of these additional online options available required students to be cautious with their studying time. For time management, the *t*-test was negative ($t(14) = -1.02$, $p = .32$), indicating that students changed their responses and agreed less with comments related to scheduling and even distribution of studying time. From the histogram (see Figure 4d), it appeared that students were more neutral after the intervention about their ability to manage their time. This may reflect that for time management, they initially assumed they were efficient, but with a comprehension of organization methods, realized their strategy was less effective. To support developmental mathematics students, Garcia (2003) used a specially designed computer package for learning, inventories of learning style and attitude, supplemental instruction, workshops, and assessments. Results were presented as measured by academic score on the final exam, and pre-and post-placement tests. Garcia recommended that students need to balance study, work, and socialization, with “well-defined and implemented time management skills” (p. 56). Although Garcia’s work was similar to this study as it used multiple approaches to support students, direct results cannot be compared, as the focus here was on the learning intervention and not on academic achievement. For this study, the creation of either a studynote or a screencast required students to manage their time effectively. Many students commented that they preferred doing the studynote; an error on a screencast required them to repeat themselves “over again and over again”, thus, taking more time. Students recognized the value of writing a studynote and because they were “only using the important info[rmation]”; it was “faster” and provided “a quick review.” According to responses from surveys A-B, students could set the pace of their own learning, and since the screencasts made students feel “like…[they] were in class again,” they could have the resources or class activities on demand. Within the learning intervention, the four activities were structured to be completed in a limited amount of time, and as the weeks progressed, required students to take greater control of the decision making. When students were requested to do both a studynote and a screencast within a 55-minute period, student comments connected strategies, time, and less stress as they planned, organized, and used their time “wisely.” From the interviews, comments of “I’m actually doing my work” were common, as perhaps (for the first time), students felt engaged and independently motivated to learn the mathematics that had previously escaped them.

Students taking developmental mathematics courses may be unaware of their poor preparation or may be reluctant to ask for assistance (Bol, Campbell, Perez, & Yen, 2016) as they are unable to actively manage their learning (Ley & Young, 1998; Vermunt, 1996; Weinstein, 2000). From the paired-samples *t*-test comparing pre- and post-intervention subscales of self-evaluation or help-seeking, the *t* values were $t(14) = .00$, $p = 1.00$ and $t(14) = .72$, $p = .48$, respectively. In addition, the pre- and post-intervention histograms looked similar. Related to self-evaluation, literature on use of formative assessment (Hudesman, Millet, Niezgoda, Han, & Flugman, 2013), homework (Bembenutty, 2009), online courseware (Spence & Usher, 2007), course records (McClain, 2015), and self-testing (Wadsworth, Husman, Duggan, & Pennington, 2007) pointed to benefits for the self-monitoring skills of developmental mathematics students. Several of these researchers noted the importance of self-regulation to foster confidence as a necessary requirement for academic achievement (e.g., Spence & Usher, 2007). For this study, students needed to self-evaluate their understanding to determine if either classmate or instructor assistance was required (help-seeking). Those students who were reluctant to share their inadequacies, may not have responded well to this subscale within the OSLQ, especially as they had a greater knowledge of the meaning of help-seeking after instruction. Moallem (2007) used the ILS to categorize students as active and reflective, and found that those who were reflective spent more time reviewing materials online. In the current study, 52.9% of participants self-reported as reflective learners, and their preference may have been to use online resources. The interviews revealed that students easily turn to Google or YouTube to find examples when problem solving, and for this study, listened to and watched the screencasts made by other students. One student commented that they could view "what…[other students] were doing" compared to "how I am doing it" to find a correct or better solution, thus, they were "able to change" their approach. Instructor reflection journal indicated that although multiple opportunities were supplied for students to monitor their progress, some students expressed concern at unanticipated test marks. Although achievement measurement was not the subject of this study, the lack of underprepared students' ability to evaluate their progress remains a challenge.

In total, the self-regulatory skills of students were increased after the intervention, which was validated by a shift in the histogram (see Figure 4g), although the paired-samples *t*-test did not demonstrate a significant difference ($t(14) = .29$, $p = .77$). The online component of the learning intervention included the use of DyKnow software and the LMS (online textbook and approximately 20 practice exercises, online activities with Web links and worksheet generators, instructor provided solutions, student artefacts, and a dropbox for sharing files). Analysis of the interview responses related to the use of DyKnow class notes found that most comments were related to task strategy and environment structuring. In class, students listened and watched the instruction (without the need to copy), so they could “really pay attention” and “take ownership.” Outside of class, responses regarding the use of the LMS related more to goal setting and time management as its organization is similar to that of an agenda or calendar. In summary, the type of affordance provided for participants appeared to closely relate to the development of certain self-regulatory skills: (a) DyKnow software with increased environment structuring and task strategy skills, (b) the LMS with the development of goal setting and time management abilities. For the remaining subscales of self-evaluation and help-seeking, the specific roles of the ICT seemed less well-defined. For self-evaluation, LMS use made it possible for students to correct their own work and reflect on sources of error. Using DyKnow software, students were able to compare both instructor and classmate solutions, and seek help by anonymously submitting their answers for in-the-moment class review and correction. The LMS housed both the studynote and screencast artefacts with the specific intention of providing classmate help for others. Students clearly found these of value, based on the tracked use of these resources, as well as the activity surveys and interviews. In the learning intervention, online affordances were designed with the specific purpose of developing student self-regulatory skills. The finding of this study is that students did use the affordances, most usually in the way anticipated. Comments from the instructor's reflective journal related to this first-time use of the dropbox to collect student artefacts. As the LMS is limited by the inability to utilize pen-based computing technology, previous to this study, it was viewed by the researcher as a one-way transmission of content (instructor to student). With the collection and posting of student created studynotes and screencasts, the dropbox allowed the transmission of content from student to instructor, and via instructor posting, back to all students. After the study, this practice of utilizing a dropbox has continued, and to overcome the limitation of hand-written notes, students take pictures of their work for submission. The instructor practice of using a dropbox to collect student artefacts during the study has now been modified into a reciprocal exchange of information.

The impact of student characteristics (demographic factors and attitude) related to the utilization of the affordances created during the learning intervention. For this portion of the study, the utilization of the affordances was measured by the number of studynote and screencast artefacts created and viewed during the learning intervention. The four activities were structured to cover mathematics topics of: (a) basic number, fraction, and proportion operations, (b) metric measurement and conversions, (c) unit conversions, and (d) conversions, rounding, scientific notation, and percent. The procedures were established with fraction operations, and applied using proportions, conversions, and percent. Conceptual understanding was demonstrated through the solving of word problems, mostly specific for the applications in chemistry or biology. Activities A-D were designed to require students to complete a studynote, a screencast, both a studynote and a screencast, and a studynote or a screencast, respectively. Of the 17 students who consented to participate in the study, all students submitted at least one studynote or screencast, with the total of 54 artefacts submitted throughout the four activities.

The instructor noted in the reflective journal some surprise that students engaged with these activities constructively. Further observations indicated that for the studynote, most students both solved the problem, as well as wrote an explanation for each step (considered instructional), while some simply solved the problem. For the screencasts, most students solved the problem while they explained their thinking, but a few already had the complete solution and audio recorded an explanation. An interesting comparison was made by one student who used the studynote to provide a rough draft of the solution, then re-wrote the work and explained it using the screencasting software. This may make for a future investigation to determine how students approach development of their media artefacts. Unexpectedly, although some of the submitted work was incorrect, students were willing to undergo the correction process publicly. For a studynote, the instructor annotated directly onto the word document, but as screencasts cannot be edited, suggestions were typed into the comment space on the LMS. The researcher was uncertain as to how students would engage with these four activities, and felt their response indicated a willingness to learn from others as well as the instructor.

The four files containing studynote and screencast artefacts were viewed on average 27 times per student in the 31 days after they were posted. To gain insight into how students were using these files, the Pearson bivariate correlation (see Table 6) indicated that students who viewed the first file (Activity A) tended to return as each of the files were posted, demonstrating they found them valuable. These viewings were not dependent on whether they had submitted artefacts themselves (see Table 5), which suggested that they were viewing the files not just to see their own work posted, but potentially for study and learning purposes. The daily tracking of student utilization confirmed this finding, as peak behaviour occurred either the day before, or the day of a quiz or test (referred to as just-in-time) viewing (see Figure 5).

From the demographic survey results (see Table 2), 70.6% of participants were 25 years of age or younger, 58.8 % were female, and 53.0% self-identified as Asian. Of the 17 participants, only seven had entered this course directly after high school, although 82.4% had taken a mathematics course in the past five years. Students classified as non-traditional (Eckel & King, 2004) or adult learners (Wuebker, 2013) have defining characteristics of an older age, have delayed entry to post-secondary, are married, have families, and are working (U.S. Department of Education, 2002). Traditional students attend higher education directly after high school, are younger, and work only part time. Based on an age classification of birth after 1982, most students in this study could be considered Millennials (Howe & Strauss, 2000) with “learning preferences tend[ing] toward teamwork, experiential activities, structure, and the use of technology” (Oblinger, 2003, p. 38). Many researchers have challenged this generalization of a homogeneous population, in particular its inference of the ICT skill level and widespread ICT use by students (Bennett, Maton, & Kervin, 2008; Brown & Czerniewicz, 2010; Dahlstrom, Brooks, Grajek, & Rees, 2015; Joiner et al., 2013; Jones, Rammau, Cross, & Healing, 2010; Kennedy, Krause, Judd, Churchward, & Gray, 2008). Underwood and Farrington-Flint (2015) have recommended a greater understanding of “the association between affordances of the technologies and learner-engagement” (p. 7).

The participants in the current study represented a mixture of both traditional and non-traditional students. A *Mann-Whitney U* test demonstrated no statistically significant number of studynotes or screencasts were submitted based on demographic factors of age, gender, or ethnicity. However, students older than 25 years viewed the artefacts posted in the LMS significantly more than younger students in preparation for the quiz assessment (see Table 9). No similar significant result was found for the use of the artefacts before the test (see Table 10). As described in the methodology, Activity D was only posted the evening before the test, so less comparative utilization by students may also have related to poor timing. It is apparent that students of all ages were viewing the artefacts in a just-in-time manner before both the quiz and test, so the finding that those of an older age may have spent more time viewing contributes little to meaning.

A Mathematics Technology Attitude Scale instrument (MTAS) (Pierce, Stacey, & Barkatsas, 2007) was used to obtain background information regarding students' opinions. Participants demonstrated high technology confidence, a moderately high attitude for affective engagement, behavioural engagement, and learning mathematics using technology, while the lowest was their mathematics confidence. The unanticipated finding was the highest value for the technology confidence of participants, an indication of the pervasive influence of technology. The low score for mathematics confidence was not unexpected from students in a Mathematics Foundations for Technology (MFT) course. Using an independent-samples *t*-test, no significant differences for MTAS subscales were found based on age, gender, or ethnicity. Using the terms 'younger' to describe those students 25 years of age or less, and 'older', to refer to those with ages greater than 25 years, interesting trends in their attitudes can be observed (see Figure 7). Although not significant, younger students had a lower mathematics confidence but higher technology confidence and attitudes towards using technology to learn mathematics than did older students. These findings were not unexpected and gave a background indication of both the traditional and non-traditional students' attitudes in this study. Further detail was illustrated from the qualitative findings of the activity surveys. As the learning intervention was designed to utilize ICT to increase student confidence, comments related to changing attitudes towards making errors were noted. Student responses showed that viewing studynotes and watching screencasts could be used not only to determine where mistakes were made, but also how they could be prevented in future work. Participants said they would be more likely to make studynotes than screencasts in future coursework, signifying that studynotes did not require them "to speak up", although some found screencasts an "innovative method to learn more [mathematics]." From the semi-structured interviews, some students confirmed they would be more likely to make a studynote because it "makes me feel more confident." Many comments regarding attitude towards making a screencast related to the audio explanation, ranging from shyness and "hate[d] being recorded", to mistakes which required creators to "start over" especially if they "can't remember" what they had previously said. Students mentioned a change in attitude regarding mathematics similar to "before [this class], I didn't like to do maths, but now I like to do math too."

The impact of learning style (active or reflective dimension) related to demographics, attitudes, self-regulation, and the utilization of the affordances of the learning intervention. To maximize opportunities for learning, researchers have determined that online course designers should take learning styles into account (Drennan, Kennedy, & Pisarki, 2005; Hawk & Shah, 2007; Rakap, 2010; Wuebker, 2013). Huang, Lin, and Huang (2012) recommended that post-secondary institutions could screen students based on learning styles "to help them assess the potential gains they will receive" (p. 347) in e-learning courses. As described in the literature review, there were no instances found of current research related to learning styles within the community college venue. This study used an Index of Learning Styles (ILS) instrument (Felder & Soloman, n.d.) to increase student understanding of how learning occurs in the mathematics classroom. With an already rich existing course format replete with multiple media provisions, the choice was made to use only the active or reflective dimension of the ILS, to gain a greater perspective of how students prefer to process information. Reflective learners process information “through introspection,” and need time to think, preferring to work by themselves, whereas active learners process information by testing ideas externally “through engagement in physical activity or discussion” (Felder & Silverman, 1988, p. 675). To benefit both styles of information processing, Karns (2006) hypothesized that reflective learners should find “thinking- and writing-based activities” effective, while active learners should prefer “experiential activities” (p. 57). With style in mind, the learning intervention was designed to benefit reflective processing of information through the writing of a summary studynote, and active processing through the creation of an audio and visually recorded screencast. The utilization of the affordances was measured by the number of studynote or screencast artefacts students either created or viewed.

The instructor/researcher noted in the reflection journal that students expressed genuine interest in their ILS scores and in the determination of their learning styles. In-class discourse centered on the idea of learning preference and what it meant, and why it might be important to know how one learns in this intervention rich with affordances. The active and reflective ILS questions were used for discussion of the characteristics of this dimension, and the scaling (mild, moderate, or strong) was used to provide a gradation. Of the 17 participants, none scored as strongly reflective nor strongly active, with the largest group (12) scoring as mildly reflective or active (see Figure 7). An unexpected finding was that almost 53% of participants scored as having a reflective learning style. From the literature, when technology is used to support learning, the student becomes an active information seeker (Caverly, Peterson, Delaney, & Starks-Martin, 2009). Research related to course design (Moallem, 2007), discussion boards (Battalio, 2009; Jeong & Lee, 2009), and community environment (Zhan, Xu, & Ye, 2011) found significant differences between active and reflective learners (as measured with the ILS). Although none of these studies were conducted with mathematics students, it is revealing that reflective learners spent more time reviewing content (Moallem, 2007), posted discussions that received a greater critical appraisal (Jeong & Lee, 2009), and had more collaborative interactions (Battalio, 2009) in the online environment. The work by Graf, Liu, and Kinshuk (2010) demonstrated that navigational behaviour within the LMS depended on learning style: reflective learners chose significantly different interaction pathways and spent more time with certain materials than did active learners. From the literature, it is apparent that the use of ICT may benefit reflective learners, in particular, as they can control the pace of their learning.

For this study, statistical interpretations were used to relate the students' active or reflective score and various measured factors (e.g., demographics, attitudes, ability to self-regulate, and utilization of studynote and screencast artefacts). An independent-samples *t*-test was conducted to compare younger (at most 25 years old) to older than 25 years students as related to active and reflective learning styles. Older students were significantly more likely to be reflective learners ($t(14.95) = 2.72$, $p = 0.02$). On the other hand, those self-identifying as Asian were significantly more likely to be active learners ($t(13.94) = 2.31$, $p = 0.04$). For this study, gender was not related to learning styles in this dimension. A comparison to the literature uncovered no analysis of demographic factors related to learning style (Graf, Liu, & Kinshuk, 2010; Jeong & Lee, 2008; Moallem, 2007). For the current study, a comparison of the individual subscales (using independent-samples *t*-test) of the MTAS did not reveal significant findings for active and reflective learners. The scatterplot and lines-of-best-fit for the five subscales of the MTAS (see Figure 9) showed that reflective learners had a lower behavioural engagement (what students do to learn in class) and attitude towards learning mathematics with technology (how it facilitates, makes math relevant, enables achievement), but a greater mathematics confidence (assurance that they can receive good grades) than did active learners. No studies were found in the literature that compared students' attitude to learning styles. There were no significant differences between total and subscale OSLQ means when related to active and reflective learning styles. When individual differences between pre- and post-intervention means of the subscales were plotted against learning style, the line of best fit indicated a positive slope. This suggested that students scoring with a more active learning style may have gained a greater self-regulation ability from the learning intervention.

A limited number of studies have shown that for courses that use online environments, students may pursue knowledge in different ways, dependent on learning styles (Garcia, Amandi, Schiaffino, & Campo, 2007; Huang, Lin, & Huang, 2012). Huang et al. categorized the utilization of resources by students taking a mixed-mode e-learning course into two groups: (a) active (the number of discussion board posts and file views), and (b) reflective (the length of time spent online and the number of page views). Using the criterion of Huang et al., utilization for this study would more closely relate to an active participation, as the measurement was the number of studynotes and screencasts created and viewed. Due to the limitations of the LMS, it was not possible to measure a passive participation. Huang et al. did not find an active or reflective learning style influenced active or passive participation in an online course. For this study, MFT students created almost twice as many studynotes as screencasts. As the creation of studynotes was considered to be a reflective behaviour, a finding that twice as many students submitted this artefact must be discussed. Possible reasons why students preferred studynotes over screencasts may be that studynotes were easier and required less time commitment. Further, in a screencast, a student must explain their mathematical thinking which may be difficult for students to articulate, particularly in a non-dominant language. Reflective learners mentioned that it was “hard to explain what I know in a form of a screencast for someone else to hear”, and they did not like hearing their own voice, even some who were “too shy to speak up.” For the learning intervention, the matches were between studynote and active learning style, and screencast and reflective learning style, yet there may have been other factors that influenced student choice when making the artefact.

Limitations of the Study

The limitations of this study included the small sample size, with the utilization of only one cohort, and that the context was restricted to one course, the Mathematics Foundations for Technology. Due to these limitations, the findings may not be generalizable to other conditions. However, this study provided relevancy as an indicator of direction for further study. In addition, the study relied heavily on the necessity of having students self-report their attitudes and opinions, both in surveys and semi-structured interviews, which may have influenced results. It is the opinion of the instructor/researcher, based on several years’ experience teaching mathematically weaker students, that they desire to overcome learning issues, thus, the expectation was that they would justify their conduct reasonably. Further, with a focus on the affordances provided by the ICT, the use of the tracking features in the LMS gave the researcher the ability to trace student access and validate student opinion. The dual role of the instructor-researcher was required to facilitate both the learning intervention, and the seamless and purposeful use of ICT. For the semi-structured interviews, the researcher hoped to have representation from each category of the active and reflective dimension, but due to small sample size, this was unobtainable.

Conclusions

This study addressed gaps in the literature related to how a learning intervention, enhanced by the affordances provided by ICT, can promote the development of self-awareness and self-regulation learning skills of Ontario community college students taking a foundational mathematics course.

It confirmed findings of Zimmerman (2008) that students can benefit from learning about self-regulation. This learning intervention had students instructed about such skills through the use of shared scaffolded notes, the creation of mathematical artefacts, and the completion of surveys. There was no significant change in their perceived self-regulation after the intervention, as measured by the OSLQ instrument (Barnard, Lan, To, Paton, & Lai, 2009). However, the responses to the activity surveys and in interviews alluded to the implementation of such skills, possibly without the students' personal recognition of growth. An unexpected finding came from their feedback in relation to the varied affordances of the ICT and the development of specific self-regulation skills. When supplied with an instructor-designed studynote or screencast, student comments related to how they might use the artefact to benefit their learning, a task strategy competency (a subscale of the OSLQ). When required to create their own artefact, student reaction was generalized to task completion, as they had to set goals, structure their environment, design task strategy and manage time effectively. Upon viewing the artefacts created by their peers, student observations specifically related to how their work compared to others, allowed the opportunity for self-correction, or to seek help upon incomplete understanding. This study demonstrated that for activity design, the self-regulation skill to be developed should first be identified and the corresponding affordance of ICT utilized. To augment self-regulation skill, contemplation must be given as to whether students should be using instructor-provided artefacts or creating/using their own.

The quantitative measure of student attitude towards mathematics, technology, and the use of technology when learning mathematics using the MTAS instrument (Pierce, Stacey, & Barkatsas, 2007) found the value for mathematics confidence to be the lowest median of all of the subscales. This is an expected finding when working with students taking a foundational course, as mathematics confidence is a reflection of the student's ability to overcome difficulty and gain assurance that good results could be obtained. The measurement of achievement was not a factor in this study, as the intervention was designed to utilize ICT to meet individual learning needs. Student comments from the interviews suggested that viewing the artefacts created by their peers was a novel and engaging way to learn, and thus, they were more likely to correct mistakes and possibly recall material more successfully.

Finally, previous assumption of the researcher expected this active, social-constructivist learning environment would benefit all learners. The finding of this study was that students appreciated being given information related to learning styles to develop a greater metacognitive awareness of how they, and their peers, learn. Due to the time constraints of the study, only the active and reflective dimensions of the ILS (Felder & Soloman, n.d.) were quantified, and based on Karns' (2006) hypothesis, the assumption made was that active students would prefer to create a screencast, while reflective learners would rather design a studynote. The finding that more than half of the participants had a reflective learning style was unexpected, yet the overall outcome was that most students were principally well-balanced for this dimension. The limited sample size did not include any participants in either of the strongly active or strongly reflective categories. Participants 25 years or younger and/or those who self-identified as Asian, significantly preferred to use the active learning option of screencasts, and during interview, commented on their enjoyment of this mode of learning. The overall finding was that students made significantly more studynotes than screencasts. Survey and interview responses clarified that writing a note on screen was easier than using the additional software and a microphone for a screencast. As screencasting required students to both write and explain their mathematical operation and process in real-time, comments related to the increased effort (e.g., more time, multiple revisions, and verbal explanations needing more planning and thinking). Interestingly though, most mentioned a greater preference for watching the dynamic screencast for review, in particular because of the audio explanation, rather than viewing a static studynote. It is evident from the just-in-time finding that students use these resources at moments convenient for their learning, most often in the wee hours of an evaluation day. Although students were familiar with writing studynotes for review, this researcher was surprised at how many had not used this practice for studying mathematics. Some students considered simply coming to class and doing online assignments as sufficient preparation for assessment. Further, none had previously written a studynote with a stylus on a Word Document, nor shared mathematics work via the LMS. In conversation, some mentioned they were familiar with video creation, but none used a stylus on a screen while recording their voice, nor had considered this technique for solving mathematics problems. In a learning intervention geared to enhance discussion and awareness of learning styles, participants gained a greater understanding of how they learn as individuals. Discussion provided students with the appropriate vocabulary to express and consider the effectiveness of their learning method, and become mindful of the possibility of alternate strategies.

Overall, this study demonstrated that a learning intervention designed for implementation in a foundational college mathematics course must take into consideration the abilities of the student to learn by becoming more aware and more self-regulated, while at the same time, for instructors to have a keen insight into how the provided affordances of the ICT are utilized by the learners.

Implications for Practice/Recommendations

Individuals can become aware of their preferences for learning by using the Index of Learning Style survey (Felder & Soloman, n.d.). In approximately 20 minutes, this survey can be taken, scored, and interpreted from a site freely available on the Web. The findings should be discussed with peers, and compared and contrasted to “see the diversity of the profile and that not all individuals learn in the same way” (Hawk & Shah, 2007, p. 14). Concluding that self-awareness can be gained through a knowledge of learning styles, Coffield, Moseley, Hall, and Ecclestone (2004) proposed that “learners can become more effective as learners if they are made aware of the important qualities which they and other learners possess” (p. 119). For students, advantages of creating their own artefacts for learning lie in the cognitive benefit related to teaching their peers, the pride of having ones’ work publicly displayed, the knowledge gained from consistent and regular use of technology, and the ability to use context-specific resources developed by their peers.

It was a finding of this study that many students were unfamiliar with the language used to discuss the importance of self-regulation skill, and thus, the development of this ability. Both traditional and non-traditional learners in the college foundational mathematics course had varying experiences of setting goals and structuring their environment, managing both their time and task, and evaluating their learning to determine if assistance was required. Further, simply offering a “buffet” of resources both inside (using pen-based computing and interactive software) and outside (extensively using the LMS) the classroom, does not guarantee the development of self-regulation. As Ley and Young (2001) suggested that outcomes can be increased with instruction in self-regulation, this learning intervention focused on giving instruction through scaffolded notes and class activities, as well as through documenting student learning and artefact creation.

Instructors can gain awareness of their teaching practice by themselves using the ILS (Felder & Soloman, n.d.). Hawk and Shah (2007) suggested that instructors in higher education may be less familiar with teaching models as they typically use “a teaching style that merges (1) the ways they prefer to learn and (2) approaches to teaching they saw as effective for their own learning in their higher education programs” (p. 1). If an instructor is knowledgeable of their students’ and their own learning style, they can increase performance by “expand[ing] the learning approaches with which adult students are comfortable and capable of learning” (p. 2). For mathematics, provision of materials in multiple modalities (e.g., text-based, audio-visual, simulations, interactive, and collaborative) allows students to express themselves in ways they believe are conducive to their learning. It is only through choice and having multiple resources that the significance of learning styles can be realized (Boekaerts, 1999). Felder (2010) suggested that learning styles are nothing more than effective pedagogy. As a first step, instructors who are unfamiliar with teaching theory are encouraged to incorporate an appropriate model and design resources that balance learning dimensions. Yet, “if the goal includes increasing students’ metacognitive awareness” (p. 4), in-class assessment of a learning style and discussion of meaning, should be undertaken. A learning intervention employing ICT provides students with a continuum of activities from which choice can be made. Using the statistics tracking features of the LMS, instructors should familiarize themselves with how and when students are using the provided resources. Web activities should be regularly updated to ensure persistent links exist. As the ICT is being used to provide instances of learning, instructors must understand the affordances of the technology, in order to make its use valuable to students. Teachers need to allow students the option of creating their own content, in particular if it is in a form that can be digitized and shared with other students.

Instructors should realize that simply developing courses using ICT does not imply that students will learn all self-regulation skills (Barnard, Lan, To, Paton, & Lai, 2009), nor necessarily develop a sought-after skill. For example, students mentioned only task strategies (i.e., how they would use it) when watching an instructor provided artefact. Dabbagh and Kitsantas (2010) and Kitsantas and Dabbagh (2011) used both the LMS and social media to determine the affordances provided by the enhanced use of ICT, and ICT's potential for the growth of self-regulation. Unlike research that measures how students are using pre-packaged resources for self-regulation improvement, this study asked students to create an artefact (studynotes or screencasts). From this researcher's point of view, the creation of an artefact in the classroom allows students to use their existing self-regulation skills, while at the same time observing and learning how their peers and teachers accomplish the task. By making the created artefacts available for all students to view, this modelling is reinforced.

A further consideration related to the development of self-regulation skill must be made of the differing environments where learning occurs. With enhanced use of ICT, it is this researcher's contention that the self-regulation skills needed for the classroom are different than those required outside of class, through the learning management system. Usually, the classroom is organized by an instructor, and the need for student self-regulation skill is dependent on the provided environment (e.g., student-centered, teacher-centered, or technology-centered). Outside of the classroom, the student assumes all responsibility for learning, although they may seek help through peers, the instructor, or the LMS. As hybrid mode uses both of these environments, instructors must take into account the varying levels of self-regulation required, which may be complemented by the affordances of ICT. Finally, instructors in professional schools must look to the development of self-regulation skills by students as a part of the requirement by industry for the so called “soft-skills” becomes more entrenched. Students graduating from college programs must be ready to step into industrial positions; course preparations that teach students how to regulate their learning are a necessity.

As mathematics already requires rational thinking, problem solving, and perseverance, the development of self-regulation ability seems a natural fit. Galbraith and Goos (2003) found that an opportunity replete with technology-enhanced learning gives students a greater ability to analyze, express and communicate their mathematical thinking with both their fellow students and their instructors. For those that have previously taken mathematics courses, and are still unsuccessful, the use of enhanced technology is a viable option to provide an enriched learning experience. Development of courses replete with the affordances supplied by ICT is time consuming and costly, requiring collaborative support from teaching teams, IT resources, and multiple levels of academic administration. A learning intervention based on the affordances provided by the ICT will only stand the test of time with a long range vision to benefit students.

Implications for Theory

The findings from this study contribute to the role of developmental mathematics and the enhanced use of ICT within the community college landscape. From a detailed literature review, there is a gap specifically related to the Ontario Community College system, and in particular, from the use of ICT within that system, as evidenced by the review of Lopes and Dion (2015). Much of the research that exists regarding the importance of developmental mathematics is based on the American Community College system. Numeracy and literacy are defined as essential skills (Dion, 2014), yet, the College Mathematics Project (CMP, 2007) found that at least one-third of first semester students in the technology cluster may be at risk of not completing their chosen program, based on their weaknesses in mathematics. Dion (2014) called for changes to both the college mathematics curriculum and to its delivery. As a step towards taking up this challenge, this study added to the published literature surrounding Ontario Colleges and the importance of developmental mathematics, and will hopefully be a catalyst to build a Canadian research base.

To develop the appropriate delivery-style of curriculum to meet the learning needs of students taking developmental mathematics courses, this work intertwined student characteristics (demographics, attitudes, learning styles, and the ability to self-regulate) with an enhanced use of ICT in a learning intervention. To this researcher's knowledge no studies have explored both learning styles and self-regulation simultaneously. In addition, most studies used only enhanced performance on tests or exams as a metric for the benefit to student learning. Working with developmental mathematics students, Garcia (2003) used a specifically designed computer package, and surveyed learning style and attitude, to determine possible advantage based on performance. Though this study was similar to Garcia's in that multiple approaches were used for support, here the focus was on learning, and the affordances provided by both the synchronous and asynchronous use of ICT.

In general, the research related to the use of ICT for students taking a developmental mathematics course is limited (Perin, 2004). There is a dearth of literature related to the use of ICT to develop student awareness of their learning style in the context of mathematics. In this study, the design of a flexible learning intervention which more closely matched the increasingly diverse requirements of both traditional and non-traditional learners was used. Unlike much of the literature which suggested ways to benefit active or reflective learning styles (Felder & Silverman, 1998), this intervention had students create artefacts to increase awareness of their personal preferences. The use of open-ended questioning and semi-structured interview gave insight into the student perspective.

With respect to the use of ICT, the latest self-regulation research looks at the affordances provided by ICT to develop and enhance the ability of students. Although not necessarily designed for college or developmental mathematics students, a demonstration of how the existing technologies may benefit students is apparent. In summary, two distinct uses of ICT are prevalent: (a) the use of the LMS (Dabbagh & Kitsantas, 2005) to advance goal setting and time management, and (b) the importance of social media (Dabbagh, 2007) as a tool to promote self-evaluation and help seeking. This research looks to the advantages and affordances of existing technology. For this study, the creation of both studynotes and screencasts during class time affords the requirement to use multiple self-regulation abilities simultaneously.

An illustrative representation of the model developed from this study is pictured below. It demonstrates how the wide scope of resources that can be afforded through the use of ICT within a learning intervention can be streamlined. To benefit students, this narrowing requires them to be able to identify how they prefer to learn, and which activities or resources are useful. In this model, the choice of active and reflective learning styles was used to develop either a screencast or studynote, respectively. Regardless of learning style choice, students were asked to create an artefact to be shared for the benefit of the learning of their peers, and to develop self-regulation skills. In order to create their artefact(s), students must set goals and structure their environment, plan their task strategy and manage their time, evaluate their product and seek-help when required. Using ICT, either a studynote or a screencast artefact can be accomplished, and in this process, students not only learn, but also understand the significance of self-regulation.

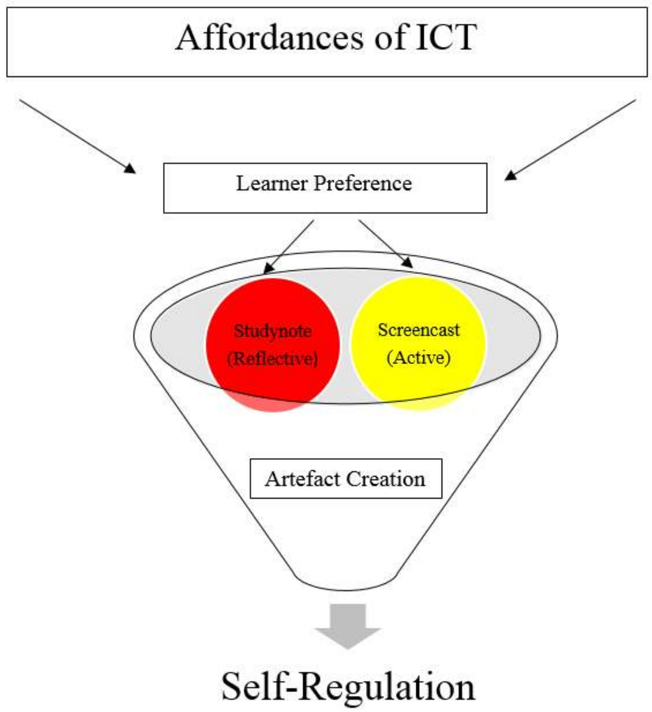


Figure 10. A model to demonstrate how the affordances of the ICT provided in a learning intervention can be streamlined to improve student self-regulation.

The findings of this study contribute to the existing theoretical landscape of the affordances of ICT and the development of self-awareness and self-regulation with the hope of increasing the learning and engagement of students in foundational mathematics courses within the Ontario Community College system.

Suggestions for Future Research

This study was founded on several years of practical experience and a genuine interest in gaining a greater perspective of how students prefer to learn. As with other small scale studies, it would be valuable to determine if the same findings are applicable for a larger sample size or with students that had a greater diversity in their learning style profiles. Further, it is necessary to know if the skill development potential found by this study can be sustained and/or transferred to other subject areas, including biology or chemistry.

In a broad based study such as this, generalizable findings are difficult to obtain, as melding learning styles, self-regulation, ICT, and mathematics together in a model that can be presented that benefits all students is next to impossible. As the theories for learning styles and self-regulation come from multiple fields, simplification and distillation of wide-ranging ideals can be difficult to obtain. Due to the newness of enhanced use of ICT in education, its benefits for learning still require further research to gain a general acceptance. In addition, research related to the use of ICT for mathematics, and in particular courses that teach developmental mathematics, is limited due to the barrier that keyboard input provides. Yet, the increased use of ICT for both traditional and non-traditional learners is becoming more of an expectation. Research into any of these aspects would bring about some welcome acumen into developing robust learning interventions. It is necessary that instructors are aware not only of what the ICT can afford students, but in a real sense, what students actually prefer to use, both inside and outside of the classroom. Further research is required to gain an understanding of how this small sample size can be scaled to the larger, and more common college class size of 70 – 80 students. In addition, further study is required to determine if the impact is only with the foundational mathematics student, in particular, is learning style awareness important for students who meet direct entry standards.

Finally, this study relied on the use of a proprietary software, based on past utilization. Additional investigation on how software such as Blackboard Collaborate or OneNote can provide a similar environment is currently underway. As the present study was limited in how the tracking of student activity was measured within the LMS, subsequent research might find a methodology to mine the data in ways that can yield more detailed information of student use of the system.

As students are continually requesting more flexible learning environments, from face-to-face to courses that are fully online, a hybrid provides a mid-way ground. Design of environments is poorly studied at the college level, yet this may be the way that learning is implemented in the future. Learning interventions that give a greater understanding of how students prefer to learn and how students can regulate their learning, while using ICT, provide a pathway to a future for students struggling in mathematics.

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APPENDIX A – INVITATION TO PARTICIPATE IN RESEARCH SCRIPT

The researcher will use the following script as an introduction:

I, like you am a student. I would like to tell you about at study that I am conducting at Seneca College, as part of my Ph.D. research with the University of Windsor.

I have taught the Mathematics Foundation for Technology Course (MTH148) for a number of years now. Just from trying different things, I have found that some students benefit from some things, others from different things, I really don't know. This year I will look at planning activities for learning, as well as going over all of the required coursework. You are not being asked to do anything beyond the coursework, as I will use course materials for part of my data. Only students that volunteer will be asked to do an interview, in July, once my course marks are submitted.

It is important for you to know that this information letter is not to tell you to join this study. It is your decision. Your participation is voluntary. Whether or not you participate in this study will have no effect on your mark in this course.

I have two different documents for you that have the same text. One is an information letter, which you can read and we will go over the major parts together and answer any questions. The second is the same information, but those that want to participate will print their names and sign the letter. Whether you sign the letter or not, place it in the envelope and seal it. You will have a second copy of the consent form to keep for your records.

APPENDIX B – LETTER OF CONSENT TO PARTICIPATE IN RESEARCH

CONSENT TO PARTICIPATE IN RESEARCH

Title of Study: Affordances of Technology-Enhanced Learning Environments for Community College Foundational Mathematics Students

You are asked to participate in a research study conducted by Carol Carruthers, Ph.D. Candidate, from the Faculty of Education at the University of Windsor. The results will contribute to the completion of a Ph.D. dissertation.
If you have any questions or concerns about the research, please contact Carol Carruthers (416)491-5050 ext 33625 (researcher), Tom McLerie (416)491-5050 ext 33245 (REB Seneca Chairperson), or Dr. Dragana Martinovic (519)253-3000 ext 3962 (Ph.D. Supervisor).

PURPOSE OF THE STUDY
The purpose of this study is to utilize the affordances (usefulness) provided by an researcher-designed learning model to develop increased self-awareness and self-regulation of first year community college students in a foundational mathematics course.

PROCEDURES
All students, regardless of whether they consent to participate in the study, will participate in all learning activities. By giving consent to participate in this study you agree to allow the researcher to use your course materials and data. If you volunteer to participate in this study, you provide permission for use of information from the course in the research (surveys, learning activities, and information about your use of the learning management system). You may be invited to take part in an individual interview about your experience in the course at a later time. You will be receiving more information about the interview at the time, and you are not consenting for the interview at this point. All parts of the study will take place only during assigned class time and will contribute to your learning. The study activities, with the exception of the interviews, will take place during the first 6 weeks of classes. You will submit your consent form (signed or unsigned) anonymously in a sealed envelope, which I will only open after my grades are submitted. Contributing to this research study will not impact grades received in this course.

POTENTIAL RISKS AND DISCOMFORTS
Potential risks include feelings of inadequacy due to weak language skills, inability to complete activities, or poor mathematics understanding. The researcher will validate your contributions in an effort to reduce these feelings. Other risks may include loss of privacy. Data collected in the research study will be kept confidential so that privacy is ensured.

POTENTIAL BENEFITS TO PARTICIPANTS AND/OR TO SOCIETY
Potential benefits include techniques to improve learning and discovering personal learning style, especially related to understanding foundational mathematics. The skills gained in this course may also be used in other subjects to benefit students.

COMPENSATION FOR PARTICIPATION
No compensation will be provided.

CONFIDENTIALITY
Any information that is obtained in connection with this study, and that can be identified with you, will remain confidential and will be disclosed only with your permission. The researcher will assign each participant a code, and all other identifying information (including names, locations, etc.) will be removed from the study. The data will be kept in a secure location in a password protected file and printed data in a locked file cabinet in a secure office. The researcher will be the only one with direct access to the data. Dr. Dragana Martinovic, Ph.D. Supervisor at the University of Windsor, may be given access to the data for analysis. The raw data will be retained until August 31, 2016, after it has been presented and defended. It will then be destroyed. Any paper collected will be confidentially shredded and the researcher will erase any electronic data. The study may include quotations from participants, however, all identifying information will be removed. As the participant, you have the right to ask the researcher about your personal data being collected for the study and about the purpose of this data. Upon the completion of the study a copy the final report will be posted on the REB website for the University of Windsor, and there is potential for its presentation at professional conferences and publication in peer-reviewed journals.

PARTICIPATION AND WITHDRAWAL
Your participation in this study is voluntary, and is not part of the requirements for the course. You may decline from participating without penalty. If you decide to participate, you may withdraw from the study at any time and for any reason(s) without explanation or penalty of any kind, June 19, 2015 is the last day to withdraw from the study. Every attempt will be made to remove your personal data and have it destroyed. You are free to not answer any question(s) that you do not wish to answer. Your decision to participate or not participate in this study will not affect your course grade. The researcher may withdraw you from this research if circumstances arise which warrant doing so.

FEEDBACK OF THE RESULTS OF THIS STUDY TO THE PARTICIPANTS
The report will be posted on the University of Windsor Research Ethics Board website.
Web address: http://www1.uwindsor.ca/reb/study-results
Date when results are available: December 2016

SUBSEQUENT USE OF DATA
These data may be used in peer-reviewed publications and in professional presentations.

RIGHTS OF RESEARCH PARTICIPANTS
If you have questions regarding your rights as a research participant, contact:
Tom McLerie, Research Ethics Chairperson, Seneca College, 70 The Pond Road, Toronto, ON, M3J 3M6; Telephone: (416)491-5050 ext 33245 REB.Chair@senecacollege.ca or
Research Ethics Coordinator, University of Windsor, Windsor, Ontario N9B 3P4; Telephone: 519-253-3000, ext. 3948; e-mail: ethics@uwindsor.ca

SIGNATURE OF RESEARCH PARTICIPANT/LEGAL REPRESENTATIVE
I understand the information provided for the study Affordance of Technology Enhanced Learning Environments for Community College Foundational Mathematics Students as described herein. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

____
Name of Participant (Please print clearly)

______________________________________   ___________________
Signature of Participant   Date

SIGNATURE OF INVESTIGATOR

These are the terms under which I will conduct research.

_____________________________________   ____________________
Signature of Investigator   Date

APPENDIX C –CONSENT TO PARTICIPATE IN INTERVIEW AND AUDIO RECORDING

Seneca

University of Windsor

CONSENT TO PARTICIPATE IN INTERVIEW AND AUDIO RECORDING

Title of Study: Affordances of Technology-Enhanced Learning Environments for Community College Foundational Mathematics Students

You are asked to participate in a research study conducted by Carol Carruthers, Ph.D. Candidate, from the Faculty of Education at the University of Windsor. The results will contribute to the completion of a Ph.D. dissertation.
If you have any questions or concerns about the research, please contact Carol Carruthers (416)491-5050 ext 33625 (researcher), Tom McLerie (416)491-5050 ext 33245 (REB Seneca Chairperson), or Dr. Dragana Martinovic (519)253-3000 ext 3962 (Ph.D. Supervisor).

PURPOSE OF THE STUDY
The purpose of this study is to utilize the affordances (usefulness) provided by a researcher-designed learning model to develop increased self-awareness and self-regulation of first year community college students in a foundational mathematics course.

PROCEDURES
You have been invited to take part in an individual interview with the researcher about your experience in the course. By giving consent to participate in this interview you agree to allow the researcher to audio-record your responses. If you volunteer to participate in this interview, you understand that this procedure is voluntary and you are free to withdraw at any time by requesting that the recording be stopped. As grades have already been submitted, contributing to this research study will not impact grades received in this course.

POTENTIAL RISKS AND DISCOMFORTS
Potential risks include feelings of inadequacy due to weak language skills, inability to complete activities, or poor mathematics understanding. The researcher will validate your contributions in an effort to reduce these feelings. Other risks may include loss of privacy. Data collected in the research study will be kept confidential so that privacy is ensured.

POTENTIAL BENEFITS TO PARTICIPANTS AND/OR TO SOCIETY
Potential benefits include techniques to improve learning and discovering personal learning style, especially related to understanding foundational mathematics. The skills gained in this course may also be used in other subjects to benefit students.

COMPENSATION FOR PARTICIPATION
No compensation will be provided.

CONFIDENTIALITY
Any information that is obtained in connection with this interview, and that can be identified with you, will remain confidential. The researcher will assign each participant a code, and all other identifying information (including names, locations, etc.) will be removed from the study. Coded audio files will be transcribed by the researcher and captured as a Word document. The data will be kept in a secure location in a password protected file and printed data in a locked file cabinet in a secure office. The researcher will be the only one with direct access to the data. Dr. Dragana Martinovic, Ph.D. Supervisor at the University of Windsor, may be given access to the data for analysis. All documents and audio files will be retained for a maximum of two years after the defence. All transcripts and electronic files will be deleted and any paper copies will be destroyed (confidentially shredded) on or before December, 2018. Data from the interview may include quotations from participants, however, all identifying information will be removed. As the participant, you have the right to ask the researcher about your personal data being collected for the study and about the purpose of this data. Upon the completion of the study a copy the final report will be posted on the REB website for the University of Windsor, and there is potential for its presentation at professional conferences and publication in peer-reviewed journals.

PARTICIPATION AND WITHDRAWAL
Your participation in this study is voluntary, and is not part of the requirements for the course. You may decline from participating without penalty. If you decide to participate, you may withdraw from the interview at any time and for any reason(s) by asking to have the recording stopped. You are free to not answer any question(s) that you do not wish to answer. Your decision to participate or not participate in this interview will not affect your course grade. The researcher may withdraw you from this research if circumstances arise which warrant doing so.

FEEDBACK OF THE RESULTS OF THIS STUDY TO THE PARTICIPANTS
The report will be posted on the University of Windsor Research Ethics Board website.
Web address: http://www1.uwindsor.ca/reb/study-results
Date when results are available: December 2016

SUBSEQUENT USE OF DATA
These data may be used in peer-reviewed publications and in professional presentations.

RIGHTS OF RESEARCH PARTICIPANTS
If you have questions regarding your rights as a research participant, contact:
Tom McLerie, Research Ethics Chairperson, Seneca College, 70 The Pond Road, Toronto, ON, M3J 3M6; Telephone: (416)491-5050 ext 33245 REB.Chair@senecacollege.ca or
Research Ethics Coordinator, University of Windsor, Windsor, Ontario N9B 3P4; Telephone: 519-253-3000, ext. 3948; e-mail: ethics@uwindsor.ca

SIGNATURE OF RESEARCH PARTICIPANT/LEGAL REPRESENTATIVE

I understand the information provided for the study Affordance of Technology Enhanced Learning Environments for Community College Foundational Mathematics Students as described herein. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

____

Name of Participant (Please print clearly)

_______________________________________ ____________________

Signature of Participant Date

SIGNATURE OF INVESTIGATOR

These are the terms under which I will conduct research.

______________________________________ _____________________

Signature of Investigator Date

APPENDIX D –INDEX OF LEARNING STYLES

Felder-Solomon Index of Learning Styles Questionnaire

NAME (please print): ____

PLEASE CIRCLE YOUR RESPONSE TO EACH QUESTION

1. I understand something better after I

(a) try it out.
(b) think it through

2. I would rather be considered

(a) realistic.
(b) innovative.

3. When I think about what I did yesterday, I am most likely to get

(a) a picture.
(b) words.

4. I tend to

(a) understand details of a subject but may be fuzzy about its overall structure.
(b) understand the overall structure but may be fuzzy about details.

5. When I am learning something new, it helps me to

(a) talk about it.
(b) think about it.

6. If I were a teacher, I would rather teach a course

(a) that deals with facts and real life situations.
(b) that deals with ideas and theories.

7. I prefer to get new information in

(a) pictures, diagrams, graphs, or maps.
(b) written directions or verbal information.

8. Once I understand

(a) all the parts, I understand the whole thing.
(b) the whole thing, I see how the parts fit.

9. In a study group working on difficult material, I am more likely to

(a) jump in and contribute ideas.
(b) sit back and listen.

10. I find it easier
(a) to learn facts.
(b) to learn concepts.

11. In a book with lots of pictures and charts, I am likely to
(a) look over the pictures and charts carefully.
(b) focus on the written text.

12. When I solve math problems
(a) I usually work my way to the solutions one step at a time.
(b) I often just see the solutions but then have to struggle to figure out the steps to get to them.

13. In classes I have taken
(a) I have usually gotten to know many of the students.
(b) I have rarely gotten to know many of the students.

14. In reading nonfiction, I prefer
(a) something that teaches me new facts or tells me how to do something.
(b) something that gives me new ideas to think about.

15. I like teachers
(a) who put a lot of diagrams on the board.
(b) who spend a lot of time explaining.

16. When I'm analyzing a story or a novel
(a) I think of the incidents and try to put them together to figure out the themes.
(b) I just know what the themes are when I finish reading and then I have to go back and find the incidents that demonstrate them.

17. When I start a homework problem, I am more likely to
(a) start working on the solution immediately.
(b) try to fully understand the problem first.

18. I prefer the idea of
(a) certainty.
(b) theory.

19. I remember best
(a) what I see.
(b) what I hear.

20. It is more important to me that an instructor
(a) lay out the material in clear sequential steps.
(b) give me an overall picture and relate the material to other subjects.

21. I prefer to study
(a) in a study group.
(b) alone.

22. I am more likely to be considered
(a) careful about the details of my work.
(b) creative about how to do my work

23. When I get directions to a new place, I prefer
(a) a map.
(b) written instructions.

24. I learn
(a) at a fairly regular pace. If I study hard, I'll "get it."
(b) in fits and starts. I'll be totally confused and then suddenly it all "clicks."
.
25. I would rather first
(a) try things out.
(b) think about how I'm going to do it.

26. When I am reading for enjoyment, I like writers to
(a) clearly say what they mean.
(b) say things in creative, interesting ways.

27. When I see a diagram or sketch in class, I am most likely to remember
(a) the picture.
(b) what the instructor said about it.

28. When considering a body of information, I am more likely to
(a) focus on details and miss the big picture.
(b) try to understand the big picture before getting into the details.

29. I more easily remember
(a) something I have done.
(b) something I have thought a lot about.

30. When I have to perform a task, I prefer to
(a) master one way of doing it.
(b) come up with new ways of doing it.

31. When someone is showing me data, I prefer
(a) charts or graphs.
(b) text summarizing the results.

32. When writing a paper, I am more likely to
(a) work on (think about or write) the beginning of the paper and progress forward.
(b) work on (think about or write) different parts of the paper and then order them.

33. When I have to work on a group project, I first want to
(a) have "group brainstorming" where everyone contributes ideas.
(b) brainstorm individually and then come together as a group to compare ideas.

34. I consider it higher praise to call someone
(a) sensible.
(b) imaginative.

35. When I meet people at a party, I am more likely to remember
(a) what they looked like.
(b) what they said about themselves.

36. When I am learning a new subject, I prefer to
(a) stay focused on that subject, learning as much about it as I can.
(b) try to make connections between that subject and related subjects.

37. I am more likely to be considered
(a) outgoing.
(b) reserved.

38. I prefer courses that emphasize
(a) concrete material (facts, data).
(b) abstract material (concepts, theories).

39. For entertainment, I would rather
(a) watch television.
(b) read a book.

40. Some teachers start their lectures with an outline of what they will cover.
Such outlines are
(a) somewhat helpful to me.
(b) very helpful to me.

41. The idea of doing homework in groups, with one grade for the entire group,
(a) appeals to me.
(b) does not appeal to me.

42. When I am doing long calculations,
(a) I tend to repeat all my steps and check my work carefully.
(b) I find checking my work tiresome and have to force myself to do it.

43. I tend to picture places I have been
(a) easily and fairly accurately.
(b) with difficulty and without much detail.

44. When solving problems in a group, I would be more likely to
(a) think of the steps in the solution process.
(b) think of possible consequences or applications of the solution in a wide range of areas.

APPENDIX E – DEMOGRAPHIC SURVEY

Identification Code Number ___________________

Demographic Survey Questions

1. What is your gender:

____

PLEASE CIRCLE YOUR ANSWER TO THE FOLLOWING QUESTIONS

2. Your current age:
    a. < 21 years
    b. 21 – 25 years
    c. 26 – 30 years
    d. 31 – 35 years
    e. > 35 years

3. What is your first language?
    a. English
    b. French
    c. Other

4. What best describes your ethnicity?
    a. Caucasian
    b. Black
    c. Caribbean/West Indies
    d. Asian
    e. South Asian
    f. Southeast Asian
    g. Latin American/Hispanic
    h. Middle Eastern/Arab
    i. Other

5. What was your educational pathway to Seneca College?
    a. Direct from secondary school
    b. Delayed
    c. Incomplete post-secondary education
    d. Complete post-secondary education

6. Your highest educational training or degree you have received.
    a. High school
    b. One year Community College Certificate
    c. Two or Three year Community College Diploma
    d. Bachelor's Degree
    e. Other – please explain

7. The highest math course you have taken:
    a. Grade 11
    b. Grade 12
    c. Community College
    d. University, please explain
    e. Non-Canadian, please explain

8. The number of years since you have taken your last mathematics course is:
    a. 0 – 5
    b. 6 – 10
    c. More than 10 years

9. What is your employment status?
    a. Full time
    b. Part time
    c. Unemployed
    d. Not in the labour force

APPENDIX F – MATHEMATICS AND TECHNOLOGY ATTITUDE SCALE (MTAS)

Mathematics and Technology Attitudes Scale

(Used with permission, Pierce, Stacey, & Barkatsas, 2005)

PLACE AN X IN THE SQUARE THAT BEST ANSWERS THE FOLLOWING QUESTIONS

	Hardly Ever	Occasionally	About half the time	Usually	Nearly Always
1. I really concentrate in mathematics.					
2. I try to answer questions the teacher asks.					
3. If I make mistakes, I work until I have corrected them.					
4. If I can't do a problem, I keep trying different ideas.					
	Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
5. I am good at using technology (e.g., computers, smart phones)					
6. I am good at using social media (Facebook, YouTube, Skype, Twitter, Instagram).					
7. I can fix simple computer problems (e.g., install printer, add programs).					
8. I can use basic computer programs needed for school (e.g., Word, PowerPoint, Excel).					
9. I like to solve math problems.					
10. I can get good results in mathematics.					
11. I know I can find ways to solve difficulties in mathematics.					
12. I am confident with mathematics.					
13. I am interested to learn new things in mathematics.					
14. In mathematics you get rewards for your personal effort.					
15. Learning mathematics is enjoyable.					

	Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
16. I get a sense of satisfaction when I solve mathematics problems.	*(This question was inadvertently omitted in participant surveys)*				
17. I like using computers for learning mathematics.					
18. Using computers in mathematics is worth the extra effort.					
19. Mathematics is more interesting when using computers.					
20. Computers help me learn mathematics better.					

APPENDIX G – ONLINE SELF-REGULATED LEARNING QUESTIONNAIRE (OSLQ)

Online Self-regulated Learning Questionnaire (OSLQ)
(Used with permission Barnard, Lan, To, Paton, & Lai, 2009)

PLACE AN X IN THE SQUARE THAT BEST ANSWERS THE FOLLOWING QUESTIONS

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1. I set personal expectations for my assignments.					
2. I set short-term (daily or weekly) goals as well as long-term goals (monthly or for the semester) for completing assigned work.					
3. I set a high standard for my learning.					
4. I set goals to help me manage my studying time.					
5. I don't compromise the quality of my work because it is online.					
6. I choose the location where I study to avoid too much distraction.					
7. I find a comfortable place to study.					
8. I know where I can study most efficiently.					
9. I choose a time with few distractions for studying.					
10. I make summary/review notes.					
11. I read aloud instructional materials (posted online) to fight against distractions.					
12. I prepare (e.g., read ahead, bring questions) before attending class.					
13. I work extra problems in addition to the assigned ones to better understand the online course content.					
14. I spend extra studying time for my online course because I know it is time demanding.					

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
15. I try to schedule time every day or every week to study, and I follow the schedule.					
16. I try to distribute my studying time evenly across the week.					
17. I find someone who is knowledgeable in course content so that I can consult with him or her when I need help.					
18. I share my problems with my classmates so we know what we are struggling with and how to solve our problems.					
19. If needed, I meet my classmates outside of class time to review/study.					
20. I am persistent in getting help from the instructor either face-to-face or through e-mail.					
21. I regularly assess my understanding of each topic.					
22. I summarize the learning in my online course to examine my understanding of what I have learned.					
23. I ask myself a lot of questions about the course material when studying for an online course.					
24. I communicate with my classmates to find out how I am doing in my online class.					

APPENDIX H – ACTIVITY A: PRACTICE QUESTIONS

Activity A: Quiz **Name: ____**

1. Classify the numbers in column **A**, using the **ALL** the terms in column **B** that apply.

Column A

$\sqrt{7}$ ______________________________

0 ______________________________

-8 ______________________________

$1\frac{2}{5}$ ______________________________

Column B

Natural	Whole
Integer	Rational
Irrational	Real

2. Draw a number line using an appropriate scale.
Illustrate the region '$x < -2.5$' using proper graphing technique.

3. Simplify the following by answering in **exponential form**.
Explain (in sentences) the exponent rules used. $2^3 \div 2^{-2} \times 2^4$

4. Using order of operations, evaluate the following. $\frac{5(8-24)}{5^2-3^2} \div 8 - 3$

5. A combination lock is given a $1\frac{3}{4}$ turn, then a $-2\frac{2}{3}$ turn, followed by a $+\frac{5}{6}$ turn.
How far has the dial been turned from its original position?

6. Simplify the following fraction question. $\frac{5}{9} \div \left(\frac{2}{3}\right)\left(\frac{2}{5}\right) + 3$

7. Using order of operations simplify using fraction rules.

Use a **WORD** to explain each step. $\left(\frac{2}{5} - \frac{2}{3}\right)^2 - \left(1\frac{3}{4}\right) \times \left(-\frac{2}{5}\right)$

8. Solve the proportion showing all steps. Round to the nearest tenth. $\frac{12.4}{6.3} = \frac{x}{4.7}$

9. A manufacturer determines that 4 out of every 25 candles will be returned.
due to defects. If they make 6750 candles, how many will not be returned?

10. The ratio of sugar to water in a mixture is 13:18. If the total mixture is 3645 mL,
what is the volume of sugar in the mixture

APPENDIX I – ACTIVITY A: INSTRUCTOR WRITTEN STUDYNOTE

Study Note Topic: Addition and Subtraction of Fractions using order of operations

What I already know:	
For mixed fractions, change to improper form first.	$2\frac{1}{4} = \frac{2\times4+1}{4} = \frac{9}{4}$
For addition and subtraction of fractions, a common denominator is required.	$\frac{5}{12} + \frac{3}{4} + \frac{1}{2}$ The common denominator is 12
A common denominator is one that all given denominators will go into.	$12\div12=1$, $12\div4=3$, $12\div2=6$ To find the factor to multiply both top and bottom by
Multiply fractions by 1 (both top and bottom by the same number) to find the equivalent fraction.	$\frac{5}{12} + \frac{3\times3}{4\times3} + \frac{1\times6}{2\times6}$
Once the common denominator is found, add/subtract the numerators, keep the common denominator.	$\frac{5+9+6}{12} = \frac{20}{12} = \frac{5}{3} = 1\frac{2}{3}$
The order of operations is Brackets, Exponents, Division/Multiplication (in order from left to right), then addition/subtraction.	

My question:

$$1\frac{1}{4} - \left(1\frac{1}{3} - 2\frac{1}{2}\right)^2 + \frac{5}{6}$$

$$= \frac{5}{4} - \left(\frac{4}{3} - \frac{5}{2}\right)^2 + \frac{5}{6}$$

- change to improper
- find a CD

$$= \frac{5}{4} - \left(\frac{8-15}{6}\right)^2 + \frac{5}{6}$$

- simplify inside the bracket first, then square the fraction

$$= \frac{5}{4} - \left(\frac{-7}{6}\right)^2 + \frac{5}{6}$$

$$= \frac{5}{4} - \frac{49}{36} + \frac{5}{6}$$

find a CD

$$= \frac{5\times9}{4\times9} - \frac{49}{36} + \frac{5\times6}{6\times6}$$

$$= \frac{45-49+30}{36}$$

$$= \frac{26}{36} = \frac{13}{18}$$

APPENDIX J – ACTIVITY A: HOW TO WRITE A STUDYNOTE

How to write a study note:

The purpose of a study note is to provide a review of important concepts and ideas that are necessary for successful study. By reviewing a study note, students learn how to summarize information. Further, it gives students a chance to see how others study, and find new strategies of which they may not be aware. A good study note provides background explanation to connect concepts previously learned and demonstrates how they are all brought together to solve a more difficulty problem. It is important that the procedures used are clear and understandable to all levels of mathematics learners. From this study note, a student should be able to successful solve similar problems of the same nature. Make sure to read the question carefully so that the solution answers the question asked.

Using the Microsoft 3 tablet:

1. Open a Word document.
2. Bring the pen close to the tablet. A pen option will appear on the top ribbon. Touch it will the pen, and multiple pen formats will appear. You are now able to write on the screen.
3. There are multiple colours of pen, thickness, eraser and highlighter (like we use in DyKnow).
4. The table format is found under the insert tab.
5. Save your word document to the desktop of your computer. On the word document, touch FILE (upper left side). From the drop down, click on "Save As". Save it on the desk top of your tablet. Name the file with the title you have given your study note.
6. Open 'My Seneca' and go to your course site MTH148SAA. Under RESEARCH, go to Activity A 'Study Note'.
7. Open 'Assignment – Student Study Notes". Submit your study note here.

With a question you find challenging:

1. First determine an appropriate title for quick reference.
2. Break down the question into parts that may need more explanation or quick review before starting.
3. Write a short note about each part with any reminders, notes, clarifications that may be required to solve the problem correctly.
4. Organize how you will present these reminders either in a table, a mind map, or picture (be creative) to make it interesting and engaging (colours).
5. Now you are ready to attempt the problem. Write a procedural point or two to clarify what you are doing at each step.

APPENDIX K – ACTIVITY A: SURVEY

Code: ________________________

Activity A Survey:

Please review the instructor provided study note and answer the following question:

1. PLACE AN X IN THE SQUARE THAT BEST ANSWERS THE QUESTION

How useful was reading this study note for your learning?

Not at all useful	Not very useful	Neutral	Somewhat useful	Very useful

Please explain why/why not the instructor provided study note was useful.

Please complete this part of the survey after you have done the activity:

1. Three things I learned about writing my own study note were:

2. I feel this activity related to my personal learning style.

Circle the correct answer: Yes No Unsure

Why/why not?

3. Would you use a study note in future coursework?

Circle the correct answer: Yes No Unsure

Why/why not?

4. Would you make a study note in future coursework?

Circle the correct answer: Yes No Unsure

Why/why not?

APPENDIX L – ACTIVITY B: PRACTICE QUESTIONS

Study sheet practice: **Name:____**

Ratio and Proportion:

1. A truck uses 54.5 L of gasoline to travel 400 miles.
   How many litres of gasoline would be needed to travel 250 miles?
2. In preparing a dinner for 25 people, the cook uses 9.5 pounds of potatoes.
   How many pounds of potatoes would be needed to serve 435 people?
3. There are 23 women and 26 men in a class of math students.
   Based on this ratio, how many women would attend a college with 10 850 students.
4. A painter can paint 220 m^2 of wall space in 8.5 hours.
   How much time would it take to paint a room of 35 m^2?

Metric Measurement (kilo to milli):

5. Convert the following metric units:

a) 1200 km = ____________ cm b) 25 mg = ______________ g

c) 5934 cm = ____________ hm d) 1000 kL = _____________mL

6. a) Convert 673280 grams to kilograms.
   b) Convert 26717 metres (m) into kilometres (km).
7. Using a microscope micrometer, the measurement of an Amoeba is 137 µm.
   What is the length of the Amoeba in mm?

Conversion between metric and imperial:

8. a) Convert 395.6 metres to feet, given 0.3048 m = 1 ft
   b) Given 1 yd = 0.9144 m, convert 98.04 m to yards.
   c) Given 1 mi = 1.609 344 km, convert 985 mi to km.
   d) Given 1 in = 25.4 mm, convert 154 inches to cm.

More than one conversion:

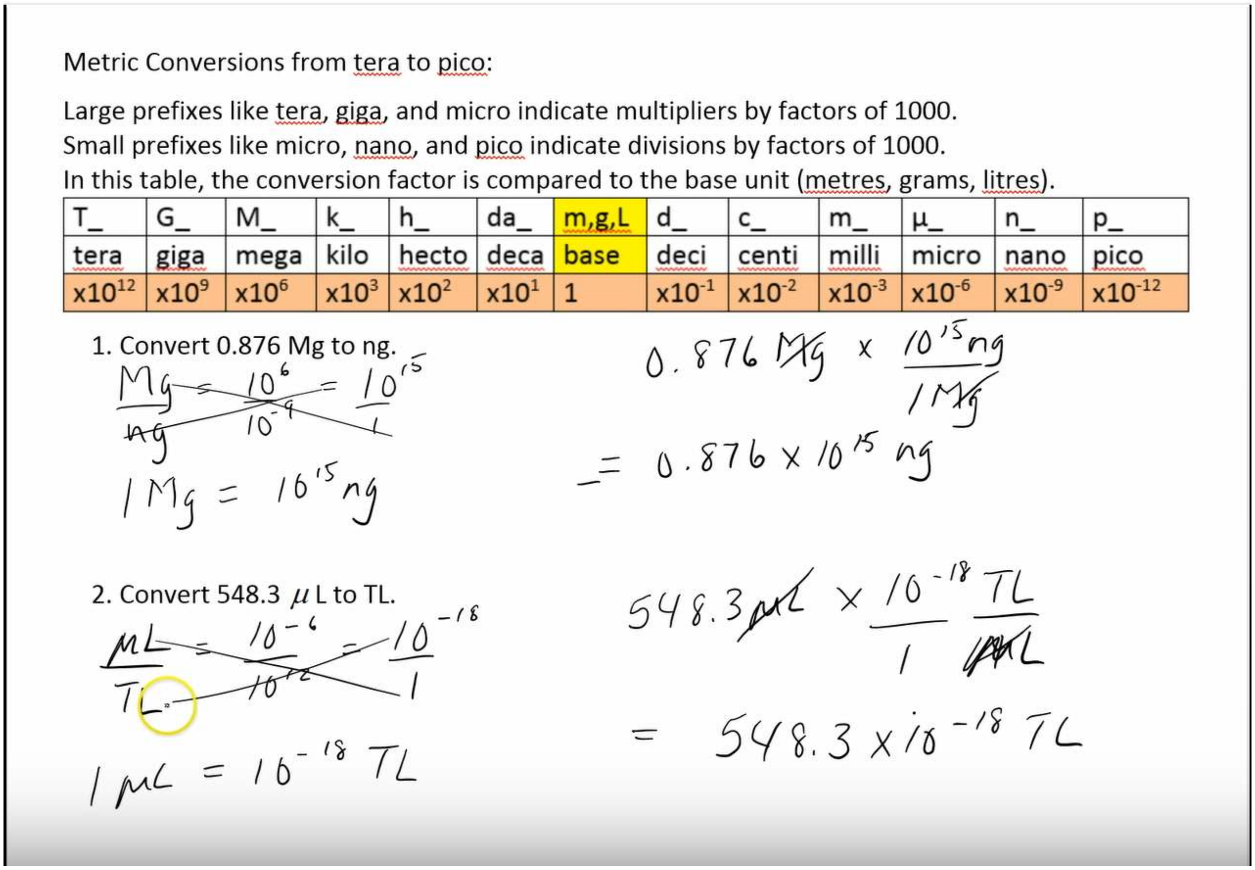
9. Convert 75.0 miles per hour (mph) to metres per second (m/s).
10. A 250 mL beaker can hold 0.196 kg of solvent. What is the density of the solvent, in g/mL?
11. Convert units for the following:
    a) 425.5 miles per hour to kmh
    b) 0.25 metres per hour to feet per min
    c) 213.45 mm/h to km/sec
    d) 0.86 mg/L to kg/mL
12. How many more metres will a car travel in 18 min at a speed of 80 km/h than it will at a speed of 60 km/h?
13. Depika cycles 2 km in 15 min and Aman cycles 24 km in 2 hours. Who cycles faster?
14. The density of a carbonic acid solution is 1.540 g/mL. How many cg/L is this?

Metric conversion (tera to pico):

15. 486.5 Tg = ________ng
16. 98.02 cm = _______Gm
17. 54.25 Mg = ________pg
18. 2.75 kL = _________GL
19. 237.23 cg = ________ng
20. 421.5 µg = _______Tg

APPENDIX M – ACTIVITY B: LINK TO INSTRUCTOR PROVIDED SCREENCAST

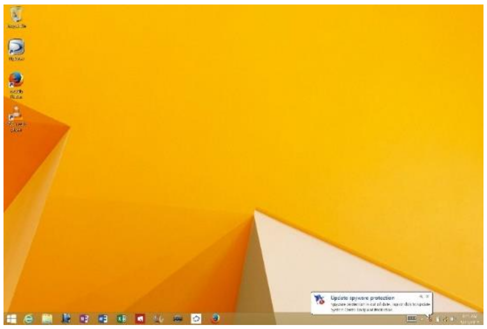
https://www.youtube.com/watch?v=yXdUtjT8UMI



APPENDIX N – ACTIVITY B: INSTRUCTIONS ON CREATING A SCREENCAST

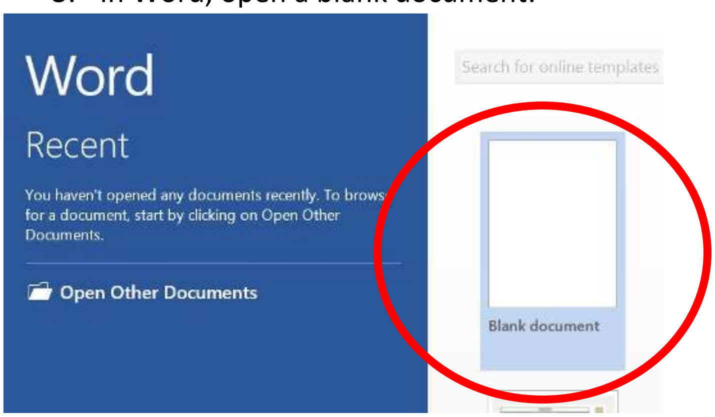
Mathcasting with the Surface Pro (as prepared by Ewan Gibson, Seneca College)

1. Go to the desktop:

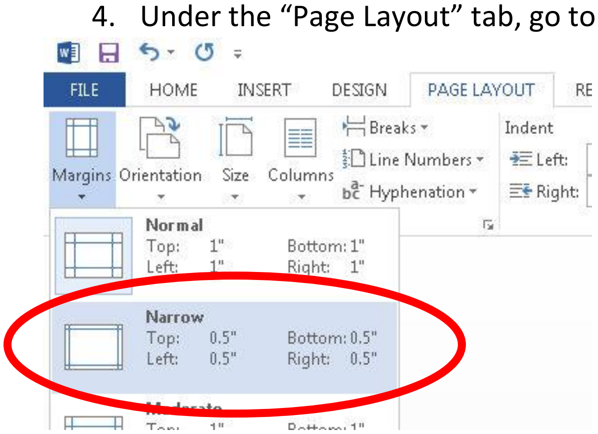


2. Open Microsoft Word:

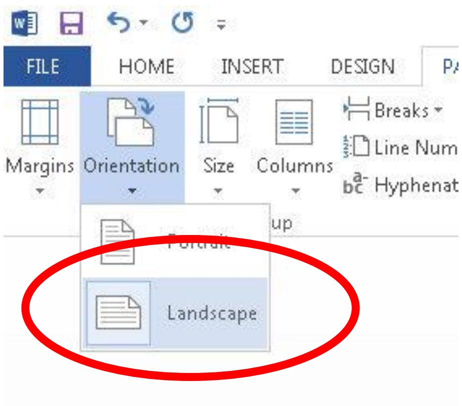
3. In Word, open a blank document:



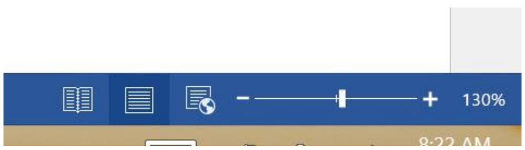
4. Under the "Page Layout" tab, go to "Margins" and select "Narrow":



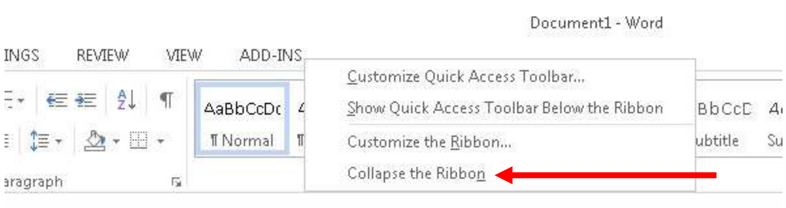
5. Still under the “Page Layout” tab, go to “Orientation” and select “Landscape”:



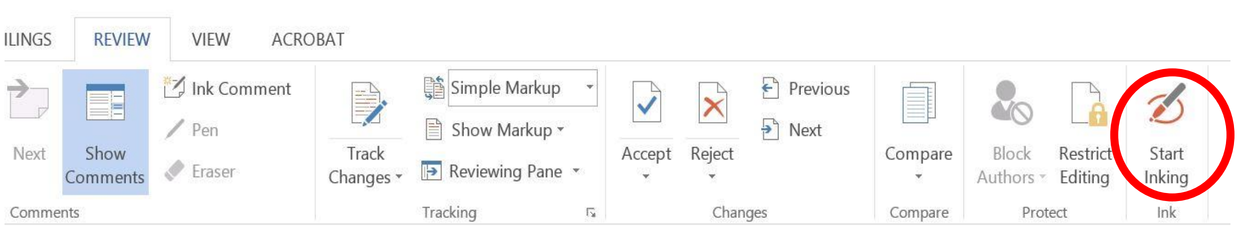
6. Enlarge your view of the document to approximately 130%:



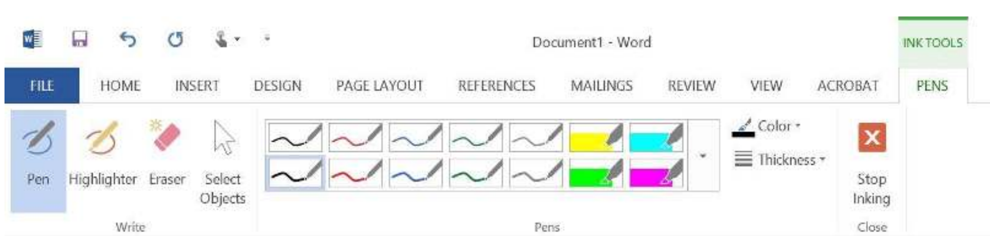
7. Right-click on any of the tabs in Word and select “Collapse the Ribbon”:



8. Go to the “Review” Tab and click on “Start Inking”



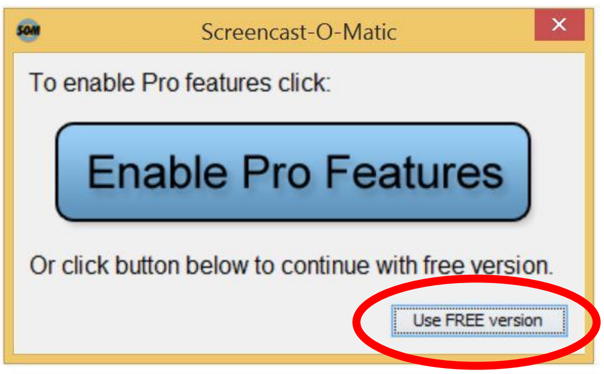
9. Select your pen and ink colour:



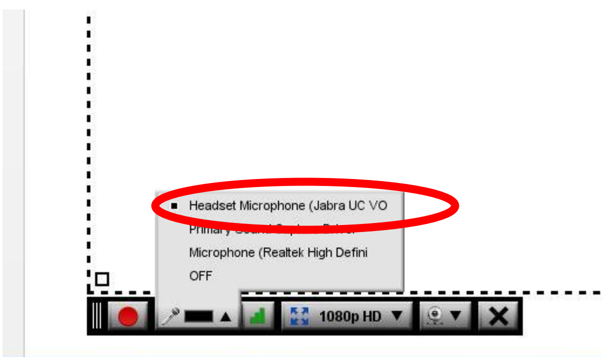
10. Insert your USB headset in the USB port on the Surface.

11. Open Screencastomatic:

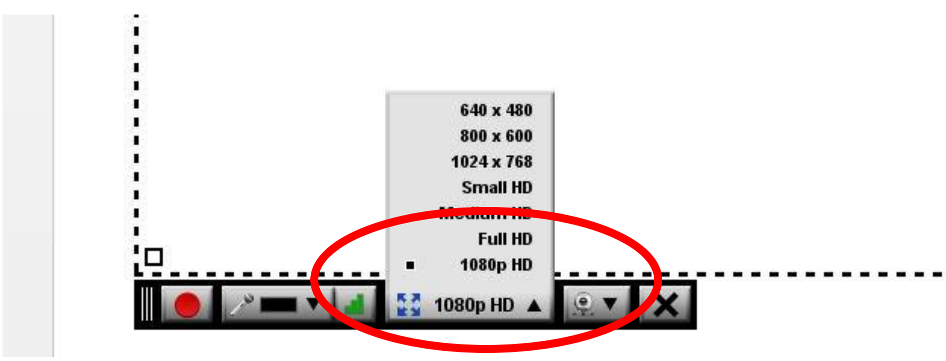
12. Choose the free version of the software:



13. Select the USB headset on the microphone menu:



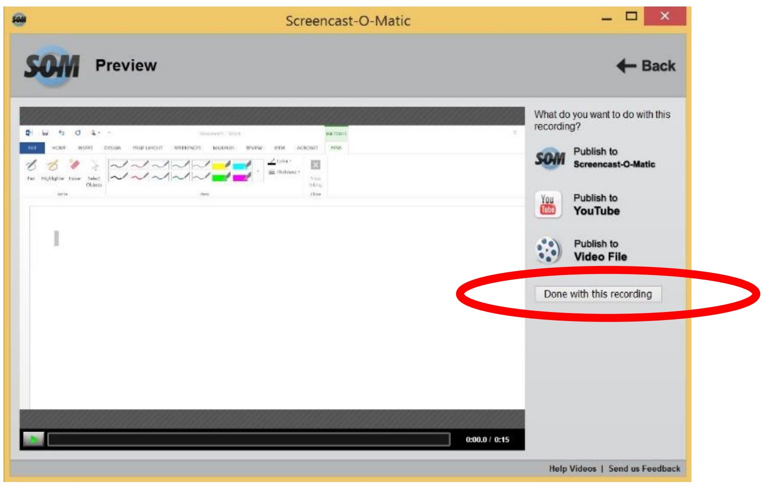
14. Select “1080p HD” from the screen size menu:



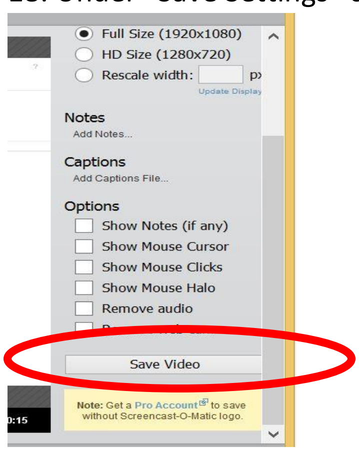
15. Click on the red Record button to begin recording. You will see a countdown “3,2,1, Start recording.” Begin your math exercise in Word.

16. Click on “Done” when you have finished recording:

17. You will see a preview screen of your video. Click on “Publish to Video File”:



18. Under “Save Settings” choose 1920x1080 and uncheck all boxes and click on “Save Video”:



19. Choose “Local Disk (T:): as your save location. Submit to the course dropbox.

APPENDIX O – ACTIVITY B: SURVEY

Code: ________________________

Activity B Survey:

Please view the instructor provided screencast and answer the following question:

1. PLACE AN X IN THE SQUARE THAT BEST ANSWERS THE QUESTION

How useful was watching this screencast for your learning?

Not at all useful	Not very useful	Neutral	Somewhat useful	Very useful

Please explain why/why not the instructor provided screencast was useful.

Please complete this part of the survey after you have done the activity:

1. Three things I learned about creating my own screencast were:

2. I feel this activity related to my personal learning style.

Circle the correct answer: Yes No Unsure

Why/why not?

3. Would you watch a screencast for future studying?

Circle the correct answer: Yes No Unsure

Why/why not?

4. Would you make a screencast for future coursework?

Circle the correct answer: Yes No Unsure

Why/why not?

APPENDIX P – ACTIVITY C: PRACTICE QUESTIONS

Activity C: Conversion Practice

1a) Convert 237.23 hg to µg b) Convert 96.18 µL to ML

2a) Convert 421.5 Tg to cg b) Convert 4.2316 GL to mL

3a) Convert 12.55 daL to pL b) Convert 76.9 cm to Mm

4a) Convert 6.5 yd to m b) Convert 2.8 in to mm

5a) Convert 53 km to mi b) Convert 906 kg to lbs

6a) Convert 648 lbs to mg b) Convert 55.4 miles to m

7a) Add 9 mL + 2 cL b) Subtract 14 km – 34 hm

8a) Four micrometers weighing 752 mg each will fit into a carton. If the carton and filler weigh 217 g, what is the total weight of the shipment?

b) How many 27 g packs of seed can be made from 2 kg of seed?

9a) How many 500 g bags are needed to hold 40 kg of grass seed?

b) Find the perimeter of a rectangle with length of 55.3 mm and width 3.41 cm.

10a) Given the area of a room is 3.5 m by 4.2 m, find the area in dam^2.

b) If a box is 2.3 cm by 4.5 cm by 3.4 cm, find its volume in mm^3.

11a) Convert 15.5 $inch^2$ in cm^2 b) Convert 87.5 $yards^2$ to km^2

12a) The volume of a box is 763 mm by 23.6 cm by 1.30 m. Find the volume.

b) The area of one side of a building is 35.8 m^2. Find this area in $yards^2$.

13a) Express 452 days in seconds.

b) Express 908 563 seconds in years.

14a) Express 34.3 km/h in terms of m/s.

b) Express 34.3 mi/h in terms of km/s.

15a) Express 4.32 lb/ft in terms of kg/m.

b) Express 12.9 m/s in terms of km/h.

16a) Express 425.5 miles per hour in kmh.

b) Express 0.25 metres per hour in feet per min.

17a) Express 213.45 mm/h in km/sec.

b) Express 0.86 mg/L in kg/mL.

18a) Convert 71 daL to m^3.

b) Convert 25 mm^3 to hL.

19a) Convert 0.003112 dg to ML (H_2O).

b) Convert 78.4 m^2 to kg (H_2O).

Given conversions:

yards to meters	**1 yd = 0.9144 m**
meters to feet	**0.3048 m = 1 ft**
inches to millimeters	**1 in = 25.4 mm**
miles to kilometers	**1 mi = 1.609 344 km**
pounds to kilograms	**1 lb = 0.45 kg**

APPENDIX Q – ACTIVITY C SURVEY

Code: ________________________

Activity C Survey:

Please complete both a studynote and a screencast activity.

1. PLACE AN X IN THE SQUARE THAT BEST ANSWERS THE QUESTION

How useful was this activity for learning about self-regulation?

Not at all useful	Not very useful	Neutral	Somewhat useful	Very useful

Please explain why/why not this activity was useful.

Please complete this part of the survey after you have done the activity.

1. Three things I learned about self-regulation were:

2. Would you apply self-regulation skills when studying for this course?

Circle the correct answer: Yes No Unsure

Why/why not?

3. Would you apply self-regulation skills in future coursework?

Circle the correct answer: Yes No Unsure

Why/why not?

APPENDIX R – ACTIVITY D: PRACTICE QUESTIONS

Activity D – Practice Questions:

1. What type of question is this? ____
Show the conversion factors used:
Convert the following metric units:
a) 180 km = ___________ cm b) 25 mg = _____________ g
c) 5934 cm = ___________ dam d) 1000 kL = ____________mL
2. What type of question is this? ____
One day last winter, 35 mm of snow fell.
Given that 1 inch = 2.54 cm, how many inches of snow fell? Show unit cancellation.
Show conversion factors used.
3. What type of question is this? ____
A student measured an iron bar that was 180 mm long, 0.0721 m wide and 3.95 cm high.
   a) Convert all measurements to meters.
   b) Determine the volume of the iron bar ($V = lwh$) in km^3.
Show conversion factors used:
4. What type of question is this? ____
A lab bench measures 650 mm by 820 mm.
What is its surface area in centimeters squared?
Show conversion factors used:
5. What type of question is this? ____
Convert 0.078 pm to Mm. Explain how you found your conversion factor.
6. What type of question is this? ____
Convert 71 daL to m^3. Explain how you found your conversion factors.
7. What type of question is this? ____
Convert 25 mm^3 to hL. Explain how you found your conversion factors.
8. What kind of question is this? ____
Convert 0.003112 dg to ML (H_2O). Explain how you found your conversion factors.
9. What is scientific notation?
Explain how to convert from ordinary notation to scientific notation.
Complete the table:

Ordinary Notation	Scientific Notation
a)678907	
b) 0.03121	
c) 0.8654	
d) 8750	
f) 670.8765	
e) 0.00008	

10. What is scientific notation?
Explain how to convert from scientific to ordinary notation.
Convert to ordinary notation:
a) 30.5×10^{-5} b) 3.6021×10^{6} c) 3.006×10^{-4} d) 100348×10^{4}

11. Explain how to round a number:
Complete the table:

Underline the digit holding the place indicated in the next column	Round to the nearest	Rounded number
162 738 495.009	hundredth	
162 738 495.009	ten thousand	
162 738 495.009	million	
162 738 495.009	hundred thousand	
162 738 495.009	tenth	
162 738 495.009	hundred	
162 738 495.009	one	
162 738 495.009	one hundred million	
162 738 495.009	ten million	
162 738 495.009	ten	

11. Explain the rounding rule used to add or subtract approximate numbers:
Complete the table:

	Calculator answer	Answer correctly rounded
368 + 605.2 - 23.809		
305.876 + 5962.7765		

13. Explain how to round numbers to 4 SF
    a) 23.1302 b) 3143500 c) 0.0025247 d) 3039009 e) 0.047588 f) 267920
14. Explain the rounding rule used to multiply and divide approximate numbers:
    Complete the following table:

	Calculator answer	Answer correctly rounded
$34667 \times 405.20 \div 28.89$		
45.86×62.787		
$0.2015 \div 46.4 \times 203.89$		

15. Explain how to convert 89.5% to a fraction and a decimal number.
    Explain how to convert the decimal number 0.036 to a fraction and percent
    Explain how to convert $5\frac{3}{7}\%$ to a fraction and decimal number.
    Explain how to convert $1\frac{4}{9}$ to a decimal number and a percent.
16. Explain how to solve the following using percent proportion.
    a) What is 68% of 8076? b) What is 0.85% of 248?
17. Explain the how to solve the follow percent questions using percent proportions.
    a) 536 is 67% of what number? b) If 22% of a number is 988, find the number.
18. Solve the following using percent proportions:
    a) 45 is what percent of 75? b) What percent of 28 is 3?

APPENDIX S – ACTIVITY D: SURVEY

Code: ____________________________

Activity D Survey:

1. Which activity (study note or screencasting) did you choose?

   Why?

2. If you were asked to do another activity, which would you choose (study notes or screencasts)?
   Why?

3. Please place and X in the response that is most appropriate:

	Yes	No	Unsure
1. I chose a location where I could work without too much distraction.			
2. I planned the steps I needed to complete this activity.			
3. I had time to work through all of the steps I planned.			
4. I practiced the questions.			
5. I managed my time effectively and completed the assignment.			
6. If I needed it, I asked someone for help.			
7. I worked hard on this practice activity and did my best job.			
8. I applied self-regulation skills that I learned to complete this activity.			

When thinking about the course so far, please comment on how effective you think you are at applying the self-regulation skills you have learned.

APPENDIX T – SEMI-STRUCTURED INTERVIEW QUESTIONS

1) a) During the first half of the mathematics course, did your **attitude** towards learning mathematics change? How so?
   b) During the first half of the mathematics course, did your **attitude** towards using technology change? How so?
   c) During the first half of the mathematics course, did your **attitude** towards using technology to learn mathematics change? How so?

2) I am aware you were learning math both **in and outside the classroom**. I would like you to tell me how you used the technology? What did you try? Can you give me some examples?

3) Remember we did the questionnaires and activities on self-awareness, and we talked about the self-awareness of a math learner. What does this mean to you?

4) In the course we used several types of activities and technology to help you learn. How do you feel each of the following contributed (or didn't) to helping you become **a more self-aware math learner**? Can you give some examples?
   a) Doing questionnaires?
   b) Writing into scaffolded learning materials delivered through a classroom learning system (DyKnow).
   c) Pen-based tablet PC computing.
   d) The course information posted on the learning management system (Blackboard Learn).
   e) Writing a studynote in a word document.
   f) Doing a screencast on the screencasting software.

5) Remember we did the questionnaires and activities on **self-regulation**, and we talked about the self-regulation of a math learner. What does this mean to you?

6) In the course we used several types of activities and technology to help you learn. How do you feel each of the following contributed (or didn't) to helping you become a **more self-regulated math learner**? Can you give some examples?
   a-f) Refer to question #4.

7) a) Which did you **like doing** better, study note or screencast, and why?
   b) Which do you feel is **better for your learning**, and why?
   c) Helping others, and why?
8) How would you compare doing the activities and using technology to your **previous mathematics experience**? Can you share what you liked or did not like about this experience?

9) From doing the activities and using the technology to learn math, what have you discovered about yourself? Is this of value to your other courses? Why/why not?

APPENDIX U - CLASS NOTEBOOKS DEMONSTRATING SELF-REGULATION

Date: June 2, 2015 **Name:** Carol Carruthers
Title of task: Measurement from kilo to milli and Conversion Factor Method

Specific Goals	1. Help students practice how to read a scale efficiently (required for lab courses). 2. Develop clear understanding of the base units and how the prefixes modify their meaning. 3. Remind students about cancelling using number examples, then explain the CFM. They must clearly understand cancelling can only occur if the unit is in the top and in the bottom. 4. Remind students of the importance of practice (instructor/websites/WileyPLUS)
Task Strategies	1. Go to websites and practice. 2. Explain, then have students practice. By submitting panels, students will demonstrate their understanding. More practice may be needed. 3. Give time to practice CFM, working in partners (group screens), so answers can be compared. 4. Have students discuss the challenge question then all work together on it. 5. Go to WileyPLUS and work on one of the assignments as a class.
Time management	Total time: 110 min (10 min break but finish at 9:40) Tablet take out and shut down takes 5 min (most students come early to class). Metric conversion from kilo to milli most students know – less time required. The conversion factor method is more challenging – need time to do plenty of examples.
Self and Environment Monitoring	Give students time to work on it on their own (reflective) or in groups (active) as is their preference. Make sure the classroom is not too noisy by checking with students frequently. Ask students if they are sitting in a place that allows them to easily get their work done.
Help-seeking	I have reviewed several websites to try to add animations and interesting features to make the work engaging. As a class, we are going to the textbook, to make sure everyone is successful with its use. Ask students about downloading DyKnow. Remind students that if they are absent they should email/go on the course site to catch up.
Evaluation	

APPENDIX V - SENECA COLLEGE RESEARCH ETHICS COMMITTEE APPROVAL LETTER

Seneca APPLIED RESEARCH & INNOVATION On Behalf of the Research Ethics Board of Seneca

May 14, 2015

To: Carol Carruthers
Email: carol.carruthers@senecacollege.ca
CC: Thomas McLerie, Chair, Seneca REB

Re: Ethics Review Application – **File #15-11**

Dear Carol Carruthers:

Thank you for applying to the Research Ethics Board (REB). I am pleased to inform you that the Seneca Ethics Review Board has approved your application to conduct the following study at Seneca College:

"Affordances of Technology-Enhanced Learning Environments for Community College Foundational Mathematics Students"

You may now begin your research.

Please note that your REB approval is contingent upon your adherence to the procedures and documents as described in the final version of the Ethics application documents that you have submitted to the REB as of this date. Should you make any substantive changes to your research process from what was described in these application documents or should you wish to do any research beyond what was described in the application in the future you will need to re-apply for Ethics Review and approval. You are not permitted to implement any changes until you have received the written approval of the REB.

Researchers are expected to keep detailed records of their research activities (i.e., interview log sheets, signed consent forms etc.) in a secure place along with the data collected and ensure that the data are destroyed in accordance with the REB approved application. Please notify me when your research has been completed.

All the best with your study.

Sincerely,

[redacted]

James Watzke, Ph.D.
Dean, Applied Research and Innovation

8 The Seneca Way, Suite 1004, Markham, Ontario L3R 5Y1
Tel: (416) 491-5050 ext. 77901, Fax: (905) 479-5461 e-mail: james.watzke@senecacollege.ca

APPENDIX W: UNIVERSITY OF WINDSOR RESEARCH ETHICS BOARD APPROVAL LETTER

Today's Date: May 13, 2015
Principal Investigator: Prof. Carol Carruthers
REB Number: 32417
Research Project Title: REB# 15-064: "Affordances of Technology-Enhanced Learning Environments for Community College Foundational Mathematics Students"
Clearance Date: May 13, 2015
Project End Date: December 30, 2016
Milestones:
Renewal Due-2016/05/11(Pending)
Renewal Due-2016/12/30(Pending)

This is to inform you that the University of Windsor Research Ethics Board (REB), which is organized and operated according to the Tri-Council Policy Statement and the University of Windsor Guidelines for Research Involving Human Subjects, has granted approval to your research project on the date noted above. This approval is valid only until the Project End Date.

A Progress Report or Final Report is due by the date noted above. The REB may ask for monitoring information at some time during the project's approval period.

During the course of the research, no deviations from, or changes to, the protocol or consent form may be initiated without prior written approval from the REB. Minor change(s) in ongoing studies will be considered when submitted on the Request to Revise form.

Investigators must also report promptly to the REB:
a) changes increasing the risk to the participant(s) and/or affecting significantly the conduct of the study;
b) all adverse and unexpected experiences or events that are both serious and unexpected;
c) new information that may adversely affect the safety of the subjects or the conduct of the study.

Forms for submissions, notifications, or changes are available on the REB website: www.uwindsor.ca/reb. If your data is going to be used for another project, it is necessary to submit another application to the REB.

We wish you every success in your research.

Alan Scoboria, Ph.D.
Chair, Research Ethics Board
Lambton Tower, Room 1102 A
University of Windsor
519-253-3000 ext. 3948
Email: ethics@uwindsor.ca

APPENDIX X: TRI-COUNCIL POLICY STATEMENT: ETHICAL CONDUCT FOR RESEARCH INVOLVING HUMANS COURSE ON RESEARCH ETHICS CERTIFICATE

PANEL ON
RESEARCH ETHICS
Navigating the ethics of human research

TCPS 2: CORE

Certificate of Completion

This document certifies that

Carol Carruthers

has completed the Tri-Council Policy Statement:
Ethical Conduct for Research Involving Humans
Course on Research Ethics (TCPS 2: CORE)

Date of Issue: **10 July, 2013**

VITA AUCTORIS

NAME:	Carol Barbara Carruthers
PLACE OF BIRTH:	Regina, Saskatchewan
EDUCATION:	Secondary School Honours Graduation Diploma C.W. Jefferys Collegiate Institute Toronto, Ontario June 1975
	Bachelor of Science York University Toronto, Ontario June 1979
	Master of Science (Graduate Programme in Biology) York University Toronto, Ontario April 1982
	Doctor of Philosophy in Educational Studies University of Windsor Windsor, Ontario November, 2016