Use of mobile devices in mathematics education: A case of higher education in the United Arab Emirates

استخدام الأجهزة المحمولة في تعليم الرياضيات: التعليم العالي في دولة الإمارات

العربية المتحدة

by

ANITA DANI

A thesis submitted in fulfilment

of the requirements for the degree of

DOCTOR OF PHILOSOPHY IN EDUCATION

at

The British University in Dubai

Supervisor's Name
Prof. Sufian Forawi

Sept-2017

Approved for award:

__________________________	__________________________
Name Designation	Name Designation
__________________________	__________________________
Name Designation	Name Designation

Date: _____________

DECLARATION

I warrant that the content of this research is the direct result of my own work and that any use made in it of published or unpublished copyright material falls within the limits permitted by international copyright conventions.

I understand that a copy of my research will be deposited in the University Library for permanent retention.

I hereby agree that the material mentioned above for which I am author and copyright holder may be copied and distributed by The British University in Dubai for the purposes of research, private study or education and that The British University in Dubai may recover from purchasers the costs incurred in such copying and distribution, where appropriate.

I understand that The British University in Dubai may make a digital copy available in the institutional repository.

I understand that I may apply to the University to retain the right to withhold or to restrict access to my thesis for a period which shall not normally exceed four calendar years from the congregation at which the degree is conferred, the length of the period to be specified in the application, together with the precise reasons for making that application.

____

Signature of the student

Abstract

The term mobile learning or m-learning refers to the educational practices in which portable, handheld computing devices are integrated. Such devices have powerful computation as well as networking features. Different types of dedicated software are available on these devices which can be used to perform more complex tasks than simple calculations, such as tasks of solving equations, drawing graphs and transforming from algebraic form to geometric and graphical representation. Intelligent tutoring software is an example of such dedicated software, which is designed to provide tutoring support to students. Intelligent tutoring programs are developed by incorporating artificial intelligence and principles of learning theories which provide tutoring support to students.

A mobile device together with software supporting these mathematics computational features forms a digital tool. Use of such digital tools enriches mathematics learning experience as they can provide visualization of abstract concepts and take off the burden of carrying out complex procedures.

This research aims to examine current practices of Apple iPad based mathematics teaching and learning in the United Arab Emirates. The focus of this research is to investigate how students in higher education institutes study foundation year mathematics courses using web-based intelligent tutor.

The investigations in this study are guided by a combined theoretical framework of the theory of instrumentation, semiotic theory and the Activity Theory. A convergent parallel mixed-method design is adopted in this study to gain understanding of students' practices and teachers' practices. Cross sectional survey method was applied for collecting quantitative data. A survey instrument consisting of items to measure perceptions, beliefs as well as study habits was developed to conduct survey research on students' population. This survey was sent to a sample of 210 students and 201 students completed the survey. Another survey instrument was designed to measure teachers' beliefs and their preferred as well as actual methods of teaching. 19 out of

26 mathematics teachers completed the survey. Qualitative data was collected from class observations.

Quantitative data was analysed by applying methods of path analysis and cluster analysis. It was revealed from the quantitative analysis that students find use of intelligent tutor effective in learning mathematics. It was found that the students are able to develop ability to learn independently by using the intelligent tutor. This ability to learn independently can be assessed from the data logs maintained by the intelligent tutor and it is found to be a significant predictor of student's academic success. Other study habits, which promote active learning, also improve their perceptions about development of conceptual understanding as well as their marks in the course. The teachers from the chosen institute have a positive attitude towards the use of digital tools in teaching mathematics and they are willing to use them to transform their teaching. From class observations, it was found that the use of interactive digital tools available on mobile devices provides opportunities for students to construct knowledge and facilitates student-centered, personalized learning. There are positive indications about the effectiveness of digital tools in mathematics education in higher education.

الملخص

يشير مصطلح (التعليم النقال) إلى التطبيقات التعليمية المدمجة بالأجهزة الحاسوبية المحمولة، وتمتلك هذه الأجهزة قدرة حاسوبية عالية، وخاصية الاتصال الشبكي؛ إذ تتوفر برامج مخصصة يمكن استخدامها لأداء مهمام أكثر تعقيدا من العلميات الحسابية البسيطة، مثل مهام حل المعادلات الرياضية، والرسوم البيانية، والتحويل من الشكل الجبري إلى التمثيل الهندسي والرسوم. إن برامج التعليم الذكي مثال على هذه البرنامج المتخصصة، إذ يتم تطوير برامج التدريس الذكي من خلال دمج الذكاء الاصطناعي ومبادئ نظريات التعلم التي توفر دعم الدروس الخاصة بالطلاب.

تعمل أجهزة المحمول جنبا إلى جنب مع هذه البرمجيات التي تدعم الميزات الحسابية الرياضية، لتكون أداة رقمية، وتستخدام هذه الأدوات الرقمية بشكل يثري تجربة تعلم الرياضيات؛ لأنها يمكن أن توفر التصور للمفاهيم المجردة وإزالة عبء تنفيذ إجراءات معقدة.

ويهدف هذا البحث إلى دراسة الممارسات الحالية في أجهزة (أبل- آي باد) على أساس تعليم الرياضيات بدولة الإمارات العربية المتحدة. وينصب تركيز هذا البحث على دراسة كيفية قيام الطلاب في كليات التعليم العالي بدراسة مقررات مادة الرياضيات للسنة الأساس باستخدام التدريس الذكي القائم على الاتصال بشبكة الإنترنت.

وتسترشد التحقيقات في هذه الدراسة من خلال الإطار النظري المشترك لنظرية استخدام القياس للتعلم، ونظرية استخدام الرموز والإشارات للتعلم، ونظرية التعلم عن طريق الأنشطة. ويتم تكييف تصميم متقارب مواز للطريقة المختلطة في هذه الدراسة للحصول على فهم لممارسات الطلاب وممارسات المعلمين. كما تم تطبيق طريقة المسح المقطعية لجمع البيانات الكمية. وقد تم تطوير أداة المسح التي تتكون من عناصر لقياس التصورات والمعتقدات، وكذلك عادات الدراسة لإجراء بحوث المسح على عينة الطلاب. وتم إرسال هذا المسح إلى عينة من 210 طلاب وقد أتم 201 طالب هذا المسح. وتم تصميم أداة استقصاء أخرى لقياس معتقدات المعلمين وأساليبهم التعليمية المفضلة وكذلك الفعلية. وقد أكمل 19 من أصل 26 معلم رياضيات هذه الدراسة، كما تم جمع البيانات النوعية من خلال الملاحظات الصفية.

لقد تم تحليل البيانات الكمية بتطبيق طرق تحليل المسارات والتحليل العنقودي. وقد كشف التحليل الكمي أن الطلاب يجدون استخدام معلم ذكي فعالا في تعلم الرياضيات، وأن الطلاب قادرون على تطوير القدرة على التعلم بشكل مستقل عن طريق استخدام المعلم الذكي. هذه القدرة على التعلم بشكل مستقل يمكن تقييمها من سجلات البيانات التي يحتفظ بها المعلم ذكي، وتبين أنه مؤشر هام للنجاح الأكاديمي للطالب.

لقد حسنت العادات الدراسة الأخرى التي تعزز التعلم النشط تصورات الطلاب عن تطوير الفهم النظري، وكذلك علاماتهم في المساق. كما أن المعلمين لديهم موقف إيجابي اتجاه استخدام الأدوات الرقمية في تدريس الرياضيات وهم على استعداد لاستخدامها لتحويل عملية التعليم. ومن الملاحظات الصفية، وجد أن استخدام الأدوات الرقمية التفاعلية المتاحة على الأجهزة النقالة توفر الفرص للطلاب لبناء المعرفة، وتسهل التعلم الذي يركز على الطالب وشخصيته. كما أن هناك مؤشرات إيجابية حول فعالية الأدوات الرقمية في تعليم الرياضيات في التعليم العالي.

Dedication

I dedicate my dissertation to my late father Gopal Kulkarni, my late mother Urmila Kulkarni and my late father-in-law Shankar Dani, who were my inspirations. They all had more confidence in my abilities than I had in myself.

I also dedicate this work to my husband Dinesh Dani and my son Anirudha Dani. They supported me actively by sharing my domestic responsibilities. They cheered me up when I was feeling low and nervous.

Acknowledgements

I am grateful to the God Almighty for giving me strength and patience to complete my research.

I thank my supervisor Prof. Sufian Forawi and co-supervisor Prof. Ramzi. I am also thankful to Prof. Eman for giving me support from time to time.

All my friends, colleagues and peers played very important role in completing my dissertation satisfactorily. My colleagues at my place of work, Mr. Akram Badoura, Mr. Ziad Traish helped me in validating the survey instrument. I must mention my friends Alyson Menzies and Shahira Elfy, who reviewed my written work and gave valuable suggestions. Other colleagues Jamal, Huda and Corey Brandon helped in collecting survey data. The departmental chairs Rob Miles and Johnson Thomas helped in getting students' and teachers' data from other campuses. My friend Elaine and my colleague Mr. Firas Al-Sammarraie translated the survey instruments and the abstract of this dissertation from English to Arabic. I thank Dr. Matthew Robby, Dr. Solomon David and Prof. Abubakr Sulaiman for reviewing the complex part of data analysis. Their suggestions were valuable in presenting my work succinctly.

Table of contents

List of Tables

List of Figures

Introduction

Different types of tools, such as slide rules, log tables, statistical tables, have been used in various forms for teaching mathematics over several years (Bates & Poole, 2003, p. 49-52). The forms of supporting tools have improved over the years and now the current tools being used are digital. A *digital tool* refers to any device that has some computing and information storing abilities beyond simple calculation abilities. In the current digital era, the word *technology* refers to hardware as well as software. Recently, different types of handheld computers, also known as mobile devices are being used for teaching and learning in secondary schools and universities (Cayton-Hodges, Feng & Pan, 2015; Dede, 2008; Drivjers et al 2010; Sharples, Taylor, & Vavoula, 2006; Trouche, & Drijvers, 2010; Olive, 2011). Examples of mobile devices are tablet computers, smart phones, iPods, personal digital assistants (PDA) and graphing calculators.

According to Dede(2008), in the 21st century, students need to master higher-order cognitive skills. They should be able to solve unstructured problems for which there is no unique and well defined problem solving strategy and which are often provided with an incomplete information. Also, they need to have social skills so that they can work with diverse teams. Dede (2008) and Olive (2011) further argue that advanced computing and telecommunication technology has the potential to develop these skills. These technologies develop rapidly and students should be familiar with the technology development. As Mourtada and Salem (2010) claim that the youth population in the Middle East region is increasing and it is important to make this youth employable in coming years. One of the important goals of university curriculum is to increase students' employability. In order to develop these skills in the graduate students, the United Arab Emirates (UAE) government is proposing to incorporate the latest technology in higher education (Gitsaki, Robby, Priest & Hamdan, 2013; Hargis, Cavanaugh, Kamali, & Soto, 2014).

Most non-mathematics major students fail to appreciate the true nature of mathematics when they encounter endless drill exercises. The tediousness of problem solving can be removed with the help of appropriate use of technology and tools. There always have been arguments in favour and against the use of technology in education. In the latest review, it is found that iPads are mainly used for communication, for accessing learning resources and for completing online assessments (Kearneya, Schucka and Burdenb, 2012). Some researchers have found that the use of iPads enhances students' learning experience but they found no clear association between iPad use and learning outcomes (Henderson, Selwyn & Aston, 2015; Nguyen, Barton, & Nguyen, 2014). It is suggested by many researchers, that improved pedagogical models are needed to increase the learning outcomes (Cochrane, 2014; Kearneya, Schucka and Burdenb, 2012; Nguyen, Barton, & Nguyen,2014; Smith, & Santori, 2015).

Bates & Poole, (2003, p. 49-52) suggest that "Learning through technology is not necessarily better or worse than face-to-face education; it is different". Accepting the fact that there is a difference between these two modes of education, the current research investigates under which circumstances, learning through using mobile devices and technology can give better results.

In the recent initiative taken by the UAE government, students and teachers in the federal higher education institutes have been provided with iPads (Gitsaki, Robby, Priest & Hamdan, 2013;). The inclusion of Information Communication Technology (ICT) in higher education will develop the 21st century skills, such as, knowledge construction, critial thinking and adaptability (Anderson, 2008). Although the driving factors for the current iPad initiative in the UAE can be considered as a *technology push* it is expected to be transformed into an *educational pull* where the driving factors will be students and teachers and not just the technology (Brummelhuis & Kuiper, 2008).

In this research, current practices of teaching and studying mathematics with mobile devices are examined. Although there are different types of mobile devices, the chosen device for this research is tablet computers, in particular iPads. Throughout this thesis, the words mobile device, handheld device, and tool are used to indicate the chosen device, which is iPad.

The rationale for this research and research questions are given in the next section.

1.1 Research questions

The effectivenss of technology based education depends on three paramters: the type of technology, ways of learning and ways of teaching (Olive, 2011). The current research questions are set to investigate these parameters to examine effectiveness of use of technology in mathematics education.

Accordingly, a broad research aim can be stated as to investigate if *the chosen technology is improving teaching and learning*. Also the current research aims to examine if the actual use of technology differs from its intended use.

This research aim is further refined into following research questions about students: *What technology do students use? How do they use it? Is it improving their learning experience*?

Additional investigation about teachers' persepctives and practices is done. The focus it to examine *How do teachers make their choices of using technology to teach mathematics? How are they actually using the technology?*

In the light of this context, the following research questions are formulated:

RQ 1: How do students perceive the suitability of iPads with appropriate software or app, to learn mathematics?

RQ 2: How are students using iPads in studying mathematics in the classroom and outside the classroom?

RQ 3: Since the introduction of the iPad initiative, up to what extent are iPads being used for teaching mathematics in universities in the UAE?

RQ 4: What types of interactions occur in the classroom where iPads are used for teaching mathematics?

1.2 Research context

This research has been carried out in one of the higher education institutes which has 17 campuses in different Emirates in the UAE. Teachers and students teaching and studying in the foundation course from different campuses of this higher education institute participated in this research. The iPad initiative has been launched recently (Gitsaki, Robby, Priest and Hamdan, 2013) and when the research was carried out, students in year two or higher had not been exposed to iPad teaching. Therefore, the focus of this research is on mathematics courses, teachers and students in the foundation year.

The target population consists of all students and teachers studying or teaching mathematics in the foundation program at this institute. The students enrolled in the foundation year program are fresh high school graduates, graduating from public schools in the United Arab Emirates. Their English language proficiency levels are weak to moderate level. The majority of the students in this program is studying two subjects, foundation English and Mathematics, but some students who met the English eligibility criteria to join the degree programs, need to take foundation mathematics courses along with their major courses. These students use a laptop or an Apple MacBook, whereas the foundation year students who are studying English and Mathematics only, use iPads. The teachers in the target population belong to different nationalities. All campuses of this institute are equipped with sophisticated and technology rich learning environment.

The most researched handheld tool in Mathematics education is a graphing calculator which comes with a dedicated software for mathematics only. This specially designed software is known as Computer Algebra System (CAS). Whereas the recently introduced tool iPad or tablet computer is equipped with a variety of apps and web-based programs. Users need to choose appropriate app or a web-based program. Such apps or web-based software systems are termed as *digital tools.* The digital tool adopted in this study is an intelligent tutoring system *ALEKS*. A detailed description of this tool is given in the next section.

1.2.1 Digital tool - ALEKS

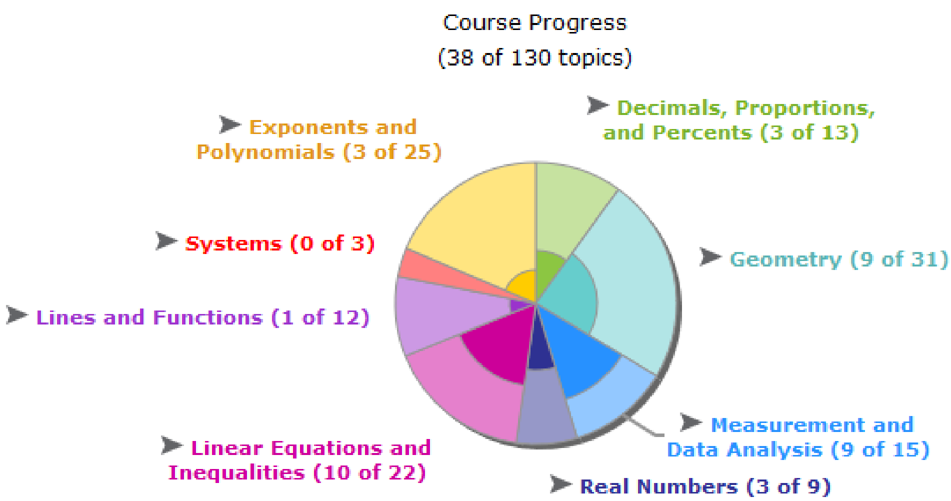
ALEKS is a web-based intelligent tutoring system, which is used in the chosen higher education institute to teach mathematics to students in the foundation program. The name ALEKS is an acronym for **A**ssessment and **L**earning in **K**nowledge **S**paces, which indicates that this software provides tutoring support and learning opportunities through frequent formative assessments.

Intelligent tutor software is developed by combining theories of cognitive science and techniques of artificial intelligence (Anderson, Boyle, Corbett & Lewis, 1990; Ritter, Anderson, Koedinger & Corbett, 2007; McGatha & Bush, 2013; Miller, 2009). The intelligent tutors can provide interactive and personalized learning environment for students, allowing them to study and learn individually (Hagerty & Smith, 2005). Due to the artificial intelligence techniques, these programs have an advantage compared to other information technologies (Chen, Yunus, Ali & Bakar 2008; Chen et al, 2008; McArthur & Stasz, 1990; McGatha, & Bush, 2013). They have the ability to integrate different audio visual mediums for presenting the course contents. With the help of this software, it is possible to provide authentic and concurrent learning activities to a large number of students.

ALEKS provides sufficient practice material for each conceptual unit to master the concept and administers frequent formative assessments to provide feedback on learning. It predicts the probability of correctness of a student's next response based on the student's previous response. It mimics the ability of an expert teacher and can confirm whether the student has mastered a conceptual unit and whether the student has retained the achieved mastery. ALEKS has the ability to create individualized sequence of topics based on the student's background knowledge and level of cognitive development. An overview of interactions between a student and the tutor is presented in the next paragraph.

When a student logs-in to this program, ALEKS, for learning, the software poses a mathematical problem which needs to be solved by the student. It can provide on-demand explanation of the topic and a step by step solution for each problem. The student can seek help by reading the explanation if required. When a student responds to the problem, ALEKS gives a feedback about the correctness of the response. If the student can answer three more similar questions on one conceptual unit correctly and without reading the explanation provided by ALEKS, then the system confirms that the student has mastered that conceptual unit. At this stage, the software provides an option of progressing to master another conceptual unit. If a student is confident about the mastery of this unit, then, he or she can click on the button 'Done,' and the topic is added to the list of 'topics mastered.' If a student gives a wrong answer, she is given a chance to correct her answer. If a student cannot answer three to four consecutive questions correctly, then the system does not present questions about the same topic but suggests that the student can try another topic. The course content and student's progress is displayed in a graphical form as shown in the Figure 1.1. This graphical view is displayed on the dashboard of the student's account.

Figure 1.1: ALEKS pie showing course content and student progress



The students use their mobile devices to access this program. The teachers use the examples from the repository of ALEKS for classroom discussion. Students benefit from these in-class discussions. They are encouraged to master the course content on ALEKS at their own pace within the given time frame and teachers are expected to monitor student's progress periodically.

Strengths of ALEKS

A mathematics course may consist of chapters consisting of coherent *conceptual units*, such as a chapter *on percentage applications* and another chapter of *geometry*. The chapter of percentages includes conceptual units such as finding percentage of total, sales tax rates, discount rates and a geometry chapter consists of concepts of perimeter, area and volume of plane and solid shapes. ALEKS runs an initial knowledge check assessment upon registering for a course. Through this knowledge test, the software checks and detects the topics that a student already has mastered. For each student, ALEKS maintains a record of a set of conceptual units, that the student has mastered. This set is termed as the *knowledge state* (Falmagne, Cosyn, Doignon, & Thiéry, 2006). ALEKS enforces that a student masters the prerequisite units before mastering any conceptual unit. For example, the conceptual unit of *finding percentage* is a pre-requisite for the conceptual unit of *finding sales tax or discount rate.* ALEKS enforces that a student must master the unit of finding percentages before allowing her to master the unit of finding sales tax or discount.

If *{a}* is a conceptual unit in the list of topics mastered and *{b}* is another conceptual unit not in that list, then the path from *{a} to {b}* is *feasible* if the conceptual unit *a* is a pre-requisite of the conceptual unit *b*. The set of all such units like the unit b, form a set of units that the student *is ready to learn* (Falmagne, Cosyn, Doignon, & Thiéry, 2006). Encouraging and supporting a student to master units by gradual progress is based on the theory of the Zone of Proximal Development (ZPD). The most important feature of ALEKS is that it designs a sequence of activities appropriate for each student and allows the student to learn at his or her own pace. As a result, it develops the student's ability to learn independently and builds confidence of problem solving.

ALEKS has the ability to generate and maintain detailed logs of each student as well as history of learning activities over the complete period of course delivery. A sample of a student's individual learning record is given in the appendix. (Refer to the Figure-A1 in Appendix-1). It displays the up-to-date status of students' progress. For each student, it records the time spent in learning and time spent on assessment. It also maintains three lists for each student. The first list includes the topics that the student has attempted, the second includes topics that the student has mastered and the third list includes topics that the student is ready to learn. These records help the teacher to identify each student's strengths and weaknesses.

Limitations of ALEKS

The ALEKS interface that was associated with the previous version at the time of research, showed the number of subunits within a unit which are yet to be mastered by the students. But it was not providing clear instructions about which are those topics and how to choose them in order to practice and master the course content.

While a student is attempting to complete all topics, the software administers periodic *progress tests* based on the topics mastered by the student. These periodic progress tests are administered by ALEKS to confirm the retention of mastery and to provide feedback to the student. In this progress assessment, some questions are taken from the list of topics which a student may not have yet mastered, but the system detects that the student is ready to learn it. Most of the students are unfamiliar with these topics. If a student fails to give the correct response to a question which has been already mastered, that topic is removed from the list of *topics mastered*. As a result, their score drops down and the student has to re-learn that topic.

It was found that many students tend to avoid these tests and often request teachers to cancel it for them. It is due to two reasons: The first reason is that the system does not provide a detailed feedback about the solution submitted during automatic progress tests and they have to relearn all topics which are not retained in the progress test. The second reason is that; weaker students get discouraged when faced with unfamiliar questions which are taken from the list of *ready to learn* topics. The objective of providing learning through assessments fails to achieve the desired result due to lack of precise feedback.

It can measure student's attainment of factual, semantic and procedural knowledge, but it fails to measure meta-cognition, because a student does not need to show the strategy used for problem solving. Many students attempt to solve problems in a mechanical manner without investigating the solution strategies.

1.2.2 Course description

Three foundation courses covering basic arithmetic, algebra, geometry and statistics are delivered using this software. The first course is numbered as M010, the second is numbered as M020 and the third course is M030. All students must pass these courses in the given sequence by getting at least 60% in each course. Each course runs over a period of eight weeks. By the end of the course, students are expected to master all learning outcomes in a course as per their learning pace. Mastery of all topics constitutes as the coursework.

There is a possibility of students getting external help in completing this coursework. Therefore, a *comprehensive assessment* is administered in class under teacher's supervision as a summative assessment. This is an individualized test, similar to a progress test based on what the student has mastered and what a student is ready to learn. After this test, the software indicates which topics are gained, retained or lost by the student during this assessment. Course mastery retained after this summative assessment is included in the final grades.

ALEKS provides teachers options of setting quizzes or homework assignments by selecting specific questions from the question pool. These quizzes are set using questions from the same topic for every student, unlike the personalized comprehensive assessments. All assessments of each course are comprehensive tests and quizzes set on ALEKS and administered in class under examination conditions.

1.3 Significance of the study

The current research literature on the effectiveness of mobile learning either highlights the issues related to teaching language skills (Aamri, & Suleiman, 2011; Ozdamar, & Metcalf, 2011) or the research findings are specific to use of graphing calculators in secondary education (Fensom, 2011; Kemp, 2011; Olley, 2011; Taylor, 2011). Although the term mobile learning indicates learning with all types of mobile devices, such as graphing calculators as well as tablet computers, there is a difference in the way these devices are incorporated into learning. Graphing calculators have a standard set of inbuilt functionalities whereas tablet computers provide options for choosing and customizing a number of apps. iPad or tablet computer based mobile learning is a separate field of research which is not fully investigated in the context of post-secondary mathematics education in the middle eastern region. Cavanaugh, Hargis, Kamali & Soto M. (2013) reported research findings about use of iPads in the UAE, but their research is not specific to teaching mathematics with iPads. The research reported in (Gitsaki and Robby, 2015) claims that after including ALEKS in the foundation year mathematics curriculum, the failure rate decreased from 30% to 17%. Gitsaki and Robby (2015) carried out their research in a similar context, but their results are based on the analysis of data collected from ALEKS. Whereas this research covers the analysis of ALEKS data as well as analysis of non-cognitive factors, such as perceptions and study habits of students and teaching practices of teachers.

This research will contribute to the existing research literature the findings about perceptions, beliefs and patterns of iPad usage by students and teachers in this region in the context of post-secondary mathematics education. In particular, it will examine the effectiveness of the intelligent tutor ALEKS in the foundation mathematics courses.

Also, this research aims to determine if there is any gap between the intended use of iPads and actual use of iPads in mathematics education. It aims to examine if there is a need to enhance current practices of using iPads in mathematics education which can be used to develop appropriate pedagogical models and to provide developmental support to teachers to enhance current practices.

This research does not cover the aspects of infrastructure, such as availability of hardware and networking. Also, it does not study aspects of institutional and management policies affecting decisions about curriculum designs as well as policies affected due to the inclusion of mobile technology.

1.4 Outline of the thesis

This thesis is organized into five chapters as follows: A comprehensive review of existing literature and description of the chosen theoretical framework is given in chapter 2. Chapter 3 consists of a description of research approach and details of the research methodology. In chapter 4 the analysis of data collected from surveys and from class observations is presented. Chapter 5 has the discussion about research findings. It also includes conclusion, recommendation, limitations and future direction of this study.

2. Theoretical framework and literature review

A theoretical framework provides an appropriate methodology and a basis for evaluation and interpretation of the findings of the research (Glesne 2011, p. 14-15). A multidisciplinary sociocultural framework, provides a broader base for interpretation of research findings (Glesne 2011, p. 36). In an attempt to reflect and theorize from a broader perspective, using the emerging research findings, the investigation of the research questions is based on the foundations of a multidisciplinary framework. The first section of this chapter describes the theoretical framework adopted for this research.

The current research encompasses the following areas: learning theories, the use of technology in mathematics education and intelligent tutors as learning tools. In the second section of this chapter, a review of literature related to these topics is presented.

2.1. Theoretical framework

According to Pachler, Bachmair & Cook (2010, p. 9), a widely accepted theory of mobile learning is not yet established. Instead, theories of integrating technology in mathematics education and the theory of human-computer interaction (HCI) are considered fundamental for investigating research questions related to mobile learning. Theories of integrating technology in mathematics education comprise of *theory of instrumentation* and *semiotic theory* (Drijvers et al 2010; Hoyles & Noss 2003, Hoyles, Noss & Kent, 2004; Lagrange, 1999; Olive, 2011; Trouche & Drijvers, 2010). The theoretical framework used for investigating human-computer interactions is based on the *Activity Theory,* which can be applied to analyze and interpret user's interactions with computers (Kutti, 2005; Uden, 2007; Sharples, Taylor, & Vavoula, 2006; Zurita, & Nussbaum, 2007). The *semiotic theory* provides a support for the interpretation of symbols in learning mathematics (Bussi & Marriotti, 2008). The framework of this research builds on the instrumentation theory, semiotic theory and Activity Theory. Each of these theories is described in the following subsections.

2.1.1 Theory of instrumentation

The theory of instrumentation proposed by Verillon and Rabardel (1995) provides a framework for understanding how cognitive development is affected by the use of tools (Trouche, 2005). This theory has been used as a theoretical foundation in many studies which examined the use of graphing calculator and computer algebra systems (CAS) in mathematics education (Hoyles, Noss & Kent, 2004; Lagrange, 1999; Misfeldt, 2013; Olive 2011; Stewart, Thomas & Hannah 2005; Thomas & Hong, 2004).

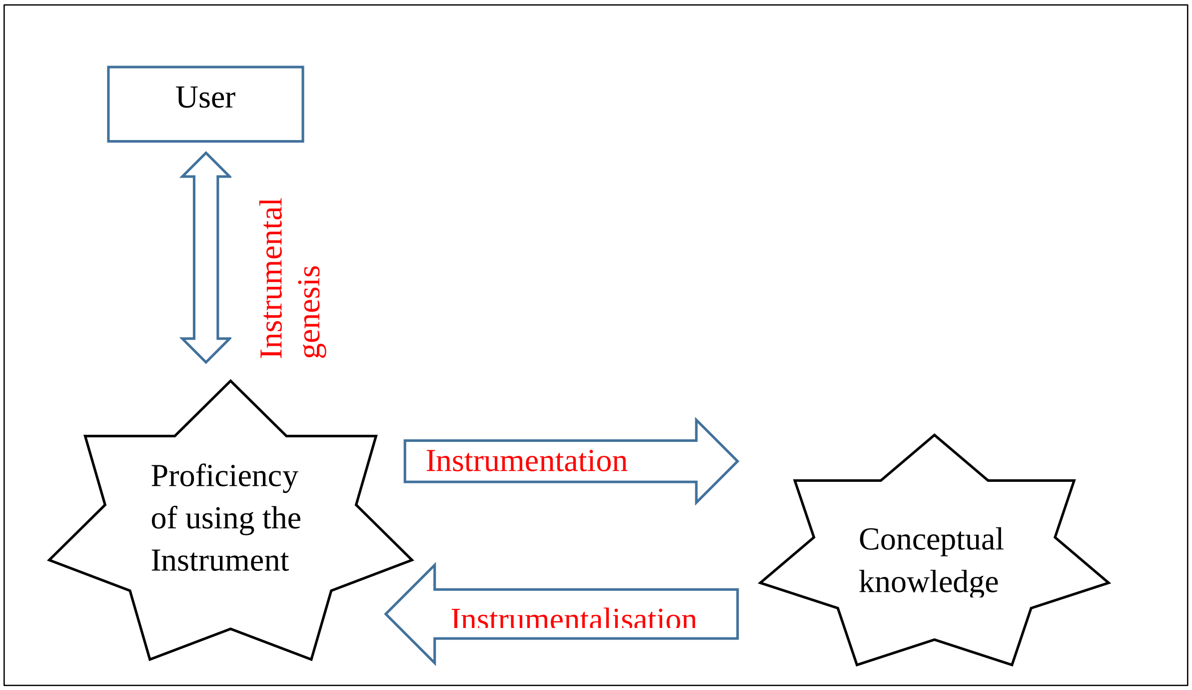
Artifacts or tools, such as iPads, are material constructs wheras an *instrument* is some material construct augmented by mental constructs of its user. A tool is transformed into an instrument by a user after being used in some activity, which requires psychological and physical participation of the user (Verillon & Rabardel, 1995; Verillon, & Andreucci, 2006).

Lagrange (1999) identified three progressive stages of tool usage as *decisional, pragmatic and interpretive*. When a student is performing a mathematical task using a tool, at the decisional level, the student is merely able to use the tool. At the pragmatic level, a student learns how to use the tool for more sophisticated usage and at the highest interpretive level, the student learns how to interpret the mathematical meaning of the result of the task. This progression describes the transformation of a tool into an instrument. The following scenario illustrates these three stages of tool usage.

Imagine a scenario where a student is using a graphing calculator. At the decisional stage, the student learns the commands to draw a graph. At the pragmatic stage, the student may learn to zoom and read details, such as the intercepts and asymptotes. The knowledge of using the tool to draw graphs as well as the knowledge of mathematical concepts of graphs, both supplement each other at this stage. At the next interpretive stage, the student can interpret the properties of the graph, the connection between algebraic and graphical representation of a function and the link between x-intercepts and roots of a function. The progression of a student from the decisional level to the interpretive level is termed as the student's *instrumental genesis.*

According to the instrumentation theory, when a student is performing a goal directed activity using a tool, the process of conceptual understanding is mediated by the tool. This is referred to as *instrumentation*. At the same time, the proficiency of using the tool is developed due to the understanding of the underlying mathematical concept. This process is referred to as *instrumentalization (*Misfeldt, 2013). As shown in the Figure 2.1, the user's proficiency of using the instrument is his instrumental genesis. Instrumental genesis is a process, which consists of both the theories of instrumentaion and instrumentalization (Heid 2005 as quoted in Olive, 2011; Misfeldt, 2013).

Figure 2.1: Theory of instrumentation



A digital tool, such as a graphing calculator influences learner's learning process and it has a role of a mediator (Noss and Hoyles, 1996 as quoted in Lagrange, 1999). The process of understanding how to use a tool for learning takes place at two different levels: *internal level* and *external level*. At the external level the user learns how to use the tool and at the internal level the user develops the knowledge about drawing meaningful conclusion from the interactions with the tool.

Theory of instrumentation stresses that each student has to develop the ability to draw meaningful conclusions from the results produced by the tool. It also emphasizes that a student develops the ability to decide when, why and how to use a tool to solve a mathematical problem. At the same time, a student must realize the fact that a problem is solved cognitively and the tool itself cannot solve the problem (Geiger, 2005).

Implication of this theory for teaching is that a teacher should set tasks which will help the students to progress from the decisional level to the interpretivist level. For a researcher, its implication is that the instrumental genesis process must be monitored over a period. This study aims to assess student's instrumental genesis developed over a period of one academic semester.

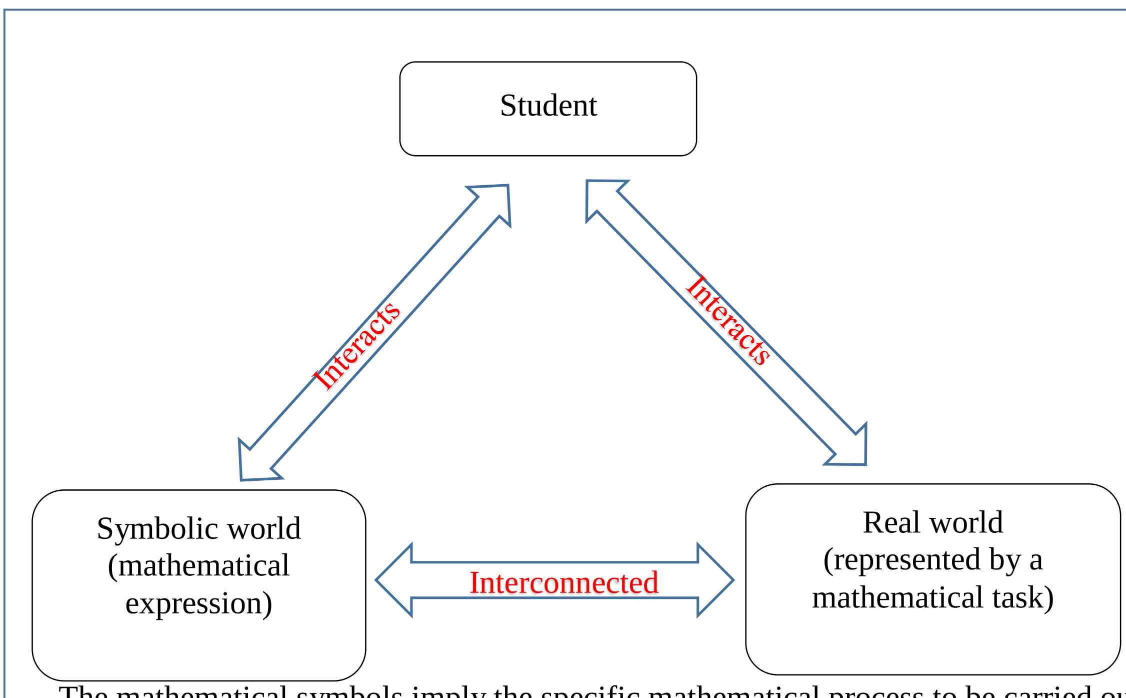
2.1.2 Semiotic theory

Mathematical concepts are expressed in compact forms using symbols. But for some students, interpretation of these symbols may become a barrier for learning (Bardini & Pierce, 2015; Bokhove & Drijvers, 2010; Bokhove & Drijvers, 2012; Lapp, Ernette, Brackett and Powell, 2013). Symbolic expressions written using mathematical symbols form a *symbolic world,* which represents the *real world* of mathematics experience. It is expected that students develop the meaning of both the worlds and the meaning which unfolds from the connection between the two worlds. This understanding deepens when the student develops ability to *interact* with both worlds (Bokhove & Drijvers, 2010; Bokhove & Drijvers, 2012). A digital tool which has the capacity of dynamic linking of multiple representations, can facilitate this learning. *Procedural understanding* is the proficiency of using the tool and *conceptual understanding* is the understanding of the mathematics concept. The ability to interpret the connection between the symbolic world and the mathematical world is developed by the *procedural* and *conceptual* understanding side by side (Heid, 2005; Tall, 2000; Tall, 2009). Figure 2. 2 shows the components of semiotic theory.

The semiotic theory links cognitive functioning to symbols and signs (Olive, 2011, Drijvers et al 2010). It addresses the epistemological issues by interpreting the relationship between the procedural and conceptual understanding. (Bardini & Pierce, 2015; Lap, Ernette, Brackett and Powell, 2013; Maracci, Cazes, Vandebrouck, & Mariotti, 2013). According to the semiotic theory, a tool used for learning mathematics generates two cognitive *schemes*, one is the skills of using the tool and the other is the ability to interpret the mathematical meaning emerging from the usage of the tool. The degree of support offered by a tool for learning mathematics is termed as its *semiotic potential*. Development of semiotic theory can be found in (Presmeg, Radford, Roth & Kadunz, 2016).

Various mathematical symbols possess predefined meanings and characteristics. The meaning of mathematical symbols is situated in a reference context, which is revealed through the interaction between the symbol and its context. The interpretation of this interaction is not subjective, but it is determined from mathematical facts and concepts (Steinbring, 2005).

Figure 2.2: Semiotic theory



The mathematical symbols imply the specific mathematical process to be carried out to get the desired solution or to construct new knowledge. The process implied by a symbol depends on its operands, which indicate the context for the symbols (Tall, 2000). The relation between the interpretation of a mathematical symbol and its context is illustrated in the following example.

For example, the symbol '+' implies a one-step *procedure* of adding two integers as in case of 8+3. Whereas, in case of fraction operands, such as $\frac{2}{3} + \frac{4}{5}$, the symbol '+' implies a *process* consisting of the following steps: first find the least common multiple (LCM) of 3 and 5, then write equivalent fractions. After that add the numbers in the numerators of the equivalent fractions and write the LCM in the denominator, finally simplify the resulting fraction. In case of an algebraic expression, such as, $x + 5$, the symbol '+' represents a *concept* of an expression which will not be a number unless some number is substituted in place of the variable x. Students are expected to learn progressively through the following stages as first learn the simple procedure implied by the symbol, then understand the meaning of a symbol as a process and then learn to unfold its abstraction as a concept. Once the highest level abstraction is understood, a student can interpret the symbol as a combination of both a process and a concept.

Ability to understand interpretation of a symbol as a procedure is termed as *operational understanding, whereas* ability to understand interpretation of a symbol as a concept is termed as *structural understanding.* For developing deep understanding of mathematical concept, both operational and structural understanding are necessary (Cangelosi et al, 2013). Though it is expected that student's understanding of mathematical symbols progresses from operational understanding to structural understanding, not all students achieve this progression. Some may get stuck at the level of procedural or operational understanding (Tall, 2000).

Tall (2000) introduced a new term *procept* to indicate the combined interpretation of a symbol as *process + concept*. Interpretation of a symbol as a *procept* leads to understanding that a mathematical symbol is a mental object which represents both a process and a concept. Those students who develop this ability, can carry out the procedure associated with the symbol as well as think about the concept represented by the symbol. The students who cannot develop this ability, find mathematics extremely complex and difficult, and their understanding of mathematics is limited only to the operational level. Tall (2000) noted that in most cases, students' conceptual understanding is under-developed in secondary schools and these weaker students lack the confidence of coping up with the higher mathematics in post-secondary classes. He further recommends that for weaker students, digital tools can provide visualization and take off the burden of carrying out complex procedures, which may encourage them to make efforts to understand symbols as procepts. At the same time, more successful students may accelerate their learning with the help of digital tools.

The design of a sound pedagogical plan should integrate both the choice of a tool with good semiotic potential and ease of developing the instrumental genesis (Drijvers et al, 2010). Lagrange, & Minh (2010) claim that identification of instrumental genesis patterns and the co-development between the operational and structural schemes facilitated by the tool, is necessary to determine under which circumstances the chosen tool is effective for learning mathematics.

2.1.3 Activity theory

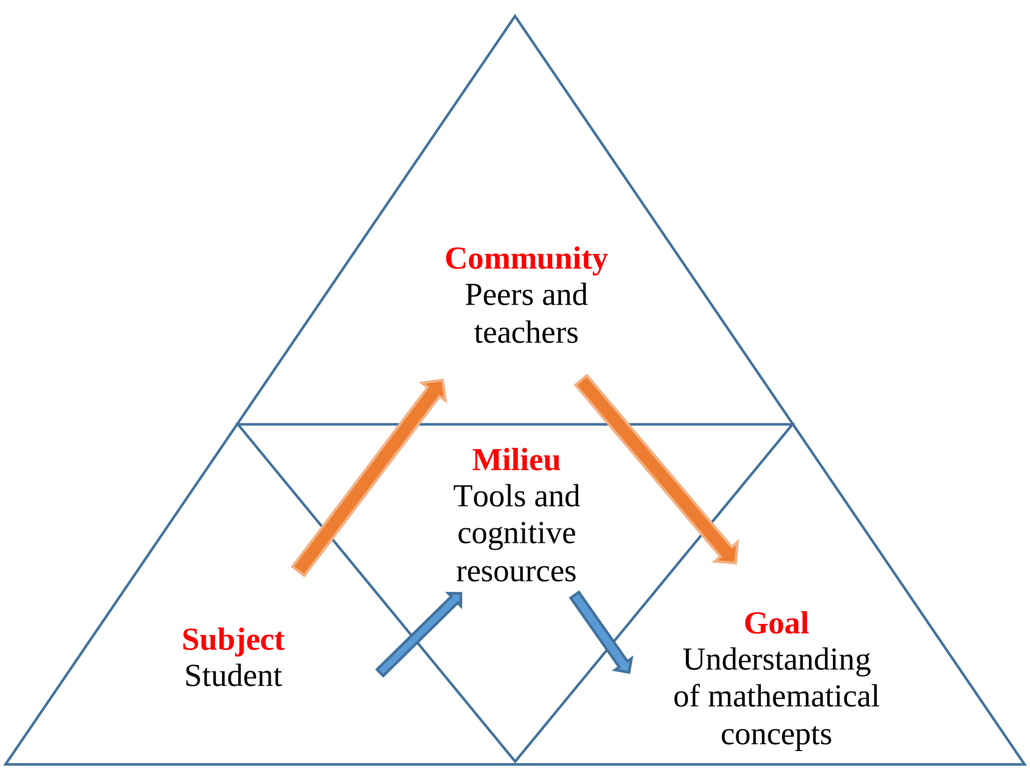
Vygotsky proposed that the association between a stimulus and the response given to it, is mediated by activities carried out with the help of artifacts (Vygotsky, 1980 quoted in Engeström, 2001). These artefacts consist of tools and signs. The Activity Theory framework has evolved from a simple first generation model proposed by Vygotsky to a more detailed second generation model developed by Engestrom (2001). According to the first generation model of Activity Theory, the following components together form a unit of analysis: Student (*subject*), mediating artifacts (*a digital tool*) and the learning goal (*object*). Engeström (2001) further developed the second generation model in which the first generation model was supported by three more components, *rules*, *community and division of labour*. These three components play a prominent role in the analysis of collaborative activities.

The Activity Theory has been used not only in the field of human-computer interaction (Kutti, 1995; Nardi 1996) but also in the field of mobile learning and mathematics education (Barab, Evans, & Baek, 2004; Batista, Behar, & Passerino, 2013; Jonassen 2000; Koole 2009; Kearneya, Schucka and Burdenb, 2012; Ozdamar &Metcalf, 2011; Drijvers et al, 2010; Uden, 2007; Zurita & Miguel, 2007). In the next paragraph, the role of Activity Theory, in the mobile learning is explained.

As noted before, a standard, widely accepted mobile learning theory is not yet established but mobile learning inherits some principles of theories of information communication technology (Pachler, Bachmair & Cook, 2010, p. 9). The mobile learning theory emphasizes the portability of the device and mobility of the learner (Sharples, Taylor, & Vavoula, 2006;Wali, Oliver, & Winters, 2009). It recommends that that there should be opportunities and support for learning which can occur across contexts and physical settings. Some of the requirements of mobile learning theory suggest the following: Mobile learning theory should theorize learning as a constructive and social process and learning should be considered as a personal as well as situated activity in which some kind of technology provided on a mobile device is used to facilitate learning. The mobile learning model is derived from the Activity Theory model as a specific collaborative learning activity in which a mobile device is used as a tool. In this model a *student is a subject* who has the *object of learning* using a mobile device as a *learning tool*. In this activity, the process of learning is influenced by the interactions between the subject and a mobile device as well as the interactions among the group members. This activity can be modelled by the first generation model of Activity Theory.

In a student centered learning environment, students are assigned a task of solving a set of real world mathematical problems. Students can use a collection of material resources, such as textbooks, digital and other tools and objective resources such as the necessary conceptual knowledge and this collection of resources is called a *milieu* (Maracci, Cazes, Vandebrouck, & Mariotti, 2013). While students are solving the mathematical tasks either individually or in collaboration, they get feedback from the milieu. Their interactions with the main digital tool, milieu, teacher and their peers help them to achieve the set learning goal. The types of interactions vary according to the mobile device and rules of interactions.

Figure 2.3: Activity Theory



More precise conceptualization of Activity Theory framework in this context is presented in the Figure 2.3. This conceptual representation focuses on the core concepts, students, milieu, community and object (goal) and interactions among them.

Critics often argue that the Activity theory is too abstract and it is not clear what binds its three components, which are tool, object and subject, together (Kaptelinin, 1996). It is due to the fact that the types of interactions among the components of this framework are specific to the tool and goal of the activity. Also, it is a descriptive tool and it does not offer standardized procedure for analysis (Engestorm, 1993 as quoted in Jonassen, 2000). The theory provides little support for analysis of the interactions among the three components. But Jonassen (2000) and Nardi (1993) have provided some guidelines for its implementation which are explained next.

Analysis of units of activity and interactions observed during the acitivty should be aimed at finding broad patterns. A wide variety of data collection sources should be used and the research time frame should be sufficiently long to reveal details of interaction patterns. It is possible to analyze the interactions of the three components by setting up a framework and by observing the activity of interest over a specific time period (Mwanza-Simwami, 2011).

On the basis of principles of the Activity Theory and the above guidelines, it is possible to analyze not just the outcome of learning but the process of learning. It is possible to analyze the nature of the activity, the type of the tool used, social and contextual relationship among the participants as well as the outcome of the activity.

The theoretical framework for this research is based on the above three theories which lays the roadmap to the research methodology and interpretation of the research findings. The following Table 2.1 summarizes how each of these theories support the investigation of current research.

Table 2.1: Theoretical framework

Name of the theory	Context of application
Theory of instrumentation	Analysis of effect of proficiency of using the tool and cognitive development on each other
Semiotic theory	Analysis of the mediating effect of the tool on the link between cognitive functioning and mathematical symbols, signs and their interpretation within a context
Activity theory (Basis of Mobile learning theory)	Investigation of interactions between student and tool and between student and community and their impact on student's learning

2.2 Literature Review

Integration of mobile devices in mathematics education should be based on theoretical foundations of mathematics education and learning philosophies as well as the learning context (Maschietto & Trouche, 2010; Trouche & Drijvers, 2010). In this section, a review of research related to the following areas is presented: learning theories, integration of technology in teaching mathematics and empirical studies which examined effectiveness of mobile learning.

2.2.1 Review of learning theories

Learning theories provide the foundation for selecting appropriate instruction strategy (Ertmer & Newby, 1993; Karagiorgi and Symeou, 2005; Dede, 2008; Tennyson, 2010). Instruction strategy using information communication technology (ICT) is closely associated with learning theories therefore, important learning theories are reviewed first. An overview of three important learning theories *behavioral, cognitive and constructivist* theory is presented below.

Behavioral theory

Thorndike (1913), Pavlov (1927), and Skinner (1974), proposed the behaviorist theory of learning. According to Skinner (1974, as cited in Ally 2004, p. 19) theory of behaviorism assumes that “learning is a change in observable behavior caused by external stimuli in the environment”. The assumption in this theory is that each behavior is observable and measurable. This theory claims that student’s behavior changes after learning and the result of learning can be assessed by observing this change. For example, consider a task of learning to download a document file from a website. Its success can be assessed by looking at its outcome only. According to this theory, it is assumed that a learner’s role is passive and learning takes place due to external stimulation. Since the learner assumes a passive role, he or she is not in a position to judge the success of outcome as well as the difficulty level of the learning task. It is the responsibility of the instructor to set the tasks in the order of their complexity as well as to assess the success of outcome. This approach was the foundation in the development of early computer systems (Ally 2004, p. 19; Cook, Gelula, Dupras, & Schwartz, 2007), but as the technology developed, new computer systems incorporated other learning theories also. These theories are discussed in the next subsections.

Cognitivist theory

According to the cognitive theory, learning is viewed as an internal process and it is affected by individual’s learning ability, existing knowledge, external environment and learner’s awareness about them (Ally 2004, p. 31). The thought process of a learner is an important aspect of learning which is overlooked by behaviorism but cognitive theory considers it as an important aspect. Principles of this theory are applicable in teaching concepts like *How to do a task*. For example, a task such as '*Find the least common multiple (LCM) of two numbers*' is based on behaviorist approach whereas a task such as '*Describe the process of finding the LCM of two numbers*' is based on cognitive approach. Learners are expected to be conscious about their learning and not as passive as postulated according to the behaviorist theory.

Constructivist theory

According to Cooper (1993) and Wilson (1997) as quoted in (Ally, 2004, p. 31), "constructivist theory claims that the learners interpret information and the world according to their personal reality and they learn by observation, processing and interpretation". Knowledge is constructued by the student and not transmitted to the student. Constructivist theory is viewed in two different perspectives of constructivism. The first is *cognitive constructivism* and the second is *social constructivism* (Cobb, 1994, Bonk & Cunningham, 1998). The first perspective claims construction of knowledge through individual experience whereas the second relates to construction of knowledge as a result of social interactions. The cognitive constructivist approach can be implemented by setting individual tasks and social constructivist approach can be implemented by setting collaborative tasks. According to the cognitive constructivist perspective, when a student encounters a new problem situation, she attempts to discover coherence across her personal experiences by mapping her previous knowledge and experience to a new experience. This discovery process leads to construction of knowledge. Whereas according to the social constructivism perspective, learner's cognitive processes are influenced by their interactions with the social context. (Muis, 2004, Cobb, Yackel and Wood, 1992). Students contribute to the development of learning activities in a mathematics classroom.

A teacher's role is important in develping the student's ability to construct new knowledge from own previous experience. The teacher can develop this ability by providing opportunities to relate a new problem situation with the previous knowledge as well as by providing counter examples. The teacher can invoke student's curiosity by changing one or more parameters and by challenging to construct different representations. Most importantly, the teacher can ask the students to reflect on their strategies and solutions as well as generate new problems (Greenes, 1995).

Problems or tasks for which there are standard and limited solutions available, are *well-structured* problems. Such problems can be solved by applying the behaviorist or cognitivist approaches. At an advanced level of learning, a student is expected to acquire ability to solve real world problems which are mostly complex and *ill-structured*. The constructivist theory is more suitable for developing this ability in students. (Jonassen, 2000)

According to the constructivist theory, the nature of the learning process is entirely *learner centered* as opposed to the teacher centered nature according to the behaviorist theory. All stages of problem solving taken by the learner are important for assessing the learning outcome and not just the end result of the task. Problem solving tasks which are designed according to the constructivist theory demand understanding of the purpose of the task. After completion of the task, the student learns the problem solving methods as well as the student can explain *Why to do this task* (Greenes, 1995*).* Though all paradigms are still applied in education, constructivism is preferred over other paradigms because it develops the ability to reason and think critically (Karagiorgi and Symeou 2005; Ertmer and Newby, 1993).

In the traditional lecture-based teaching practices knowledge is transmitted directly, which may lead to superficial learning. It may not facilitate learning by constructing new knoweldge and may fail to develop problem solving abillity (Hannafin, and Land, 1997). In such type of traditional learning environments, the focus is on the teacher whereas in the innovative learning environments this focus is shifted to students and the teacher assumes the role of a facilitator. Hannafin, and Land (1997) describe a student-centered learning environment as the environment in which students are encouraged to contribute actively in the development of the learning activity. The assumption of such learning environment is that when students are assigned a problem solving task, they apply their prior knowledge to solve new problems but also get scaffolding support from the teacher or other digital resources. As they attempt to solve a new problem, they get feedback from the teacher or from the tools that they use. Based on this feedback they also get an opportunity to improve and adjust their problem solving strategies. In such problem solving activities digital tools can be used to stimulate thinking and doing experiments. When digital tools are incorporated in the student-centered learning environment, it becomes easy to assign progressive and multiple levels of complexity (Georgia and Symeon, 2010; Hegedus and Tall, 2016; Hegedus et all, 2017).

It is necessary to examine how these learning theories are supported by the software features available on the mobile devices. Dede (2000) proposed classification of software and tools into three different categories on the basis of learning theories supported by them. As given in (Dede, 2008) computer assisted instructions and learning management systems available on mobile devices support behaviorist approach, intelligent tutoring systems support cognitive approach and simulation tools support constructivist approach. Dede (2008) claims that choosing appropriate technology in instructions and assessments can help in reforming the curriculum without changing the content.

The intelligent tutor ALEKS which is being investigated as the main learning tool, incorporates two important paradigms in education, the zone of proximal development (ZPD) and scaffolding as well as use of assessments for learning. These two concepts are reviewed in the next two subsections.

ZPD and scaffolding

Vygotsky formulated the concept of zone of proximal development (ZPD). It refers to the gap between 'what a student can do alone' and 'what he can achieve with the support from an expert' (Wood and Wood, 1996).

The expert is also termed as *the tutor* and the interactions between the tutor and the student are termed as *tutorial interactions*. These tutorial interactions are termed as 'scaffolding'. The parallels between the notion of scaffolding and Vygotsky's concept of ZPD are given in Wood and Wood (1996). An expert tutor establishes task-related goals and guides the learner towards them. Expert tutor also avoids setting too complex or too easy tasks to ensure that the student does not give up due to high complexity of the task, at the same time gains some new knowledge (Dani, 2015). Although, initially the student may heavily depend on the tutor's guidance eventually the responsibility of problem solving is transferred from the tutor to the student (Thelwall, 2000). It is expected that a tutor develops higher order skills, such as ability to choose the right problem solving strategy and the ability to apply acquired knowledge to solve new problems (Dani, 2016).

Deep learning happens when a learner is able to transfer existing knowledge to solve new problems. Inability to transfer prior knowledge to a new situation is termed as *shallow learning* (Aleven, and Koedinger, 2002, Chi et al 1989). An expert tutor has the ability of developing learner's metacognitive strategy. Due to the metacognitive ability, the learner can explain the acquired knowledge and transfer her existing knowledge to solve problems in a new situation (Aleven, and Koedinger, 2002).

According to the constructivist learning paradigm, the purpose of education is to cultivate independent and self-directed students. Scaffolding provides a strategy to implement these goals of constructivist learning paradigm (Kao and Lehman, 1997, Belland, 2017).

Computer aided instructions can integrate more than one medium. They can also provide authentic learning activities which provide support to many students at the same time in a classroom setting. But computer supported tutoring is still not as effective as human tutoring. It is found by many researchers that human tutoring has an effect size of d = 2.0 relative to classroom teaching without tutoring, which is known as the 'two sigma gain' (Dani, 2015; VanLehn, 2011). Human tutoring is more effective than computer tutoring due to appropriate feedback and scaffolding techniques. Human tutors provide scaffolding based on the ability of the student. In an attempt to achieve the same effect, efforts are being made to embed three characteristics of human tutors into the tutoring software, which are knowledge of the subject, knowledge of the student and knowledge of teaching (Mark, and Greer, 1993; Sabo et al, 2013). Tutoring systems which embed these three characteristics with the help of techniques of artificial intelligence are known as *intelligent tutoring systems*. A review of intelligent tutors is given in section 2.2.3.

Assessments

Assessments are important milestones in the process of teaching as they provide information about students' current state of knowledge. For students, assessments provide an opportunity to reflect on their learning. Teachers can incorporate outcomes of assessments in their teaching, in order to improve students' academic achievement and enhance teaching and learning (Stiggins and Chappuis, 2005). Formative and summative assessments are important for reviewing acquisition and retention of knowledge. Shepard (2000) argues that assessments are not just meant for giving rewards or punishment but they are also an important source of learning. She further proposes that assessment strategies and instruments should have cognitive as well as motivational purpose. Assessment strategy can have one or more of the following objectives: assessment of prior knowledge, evaluation of effectiveness of teaching and identifying any gap between expected learning and actual learning (Chappuis, 2014, pg. 15; Shepard, 2000).

In the foundation year, students experience transition from school to university. They have fewer face-to-face teaching sessions with their instructor than they have in school (Dani, 2015; Nicol, 2006). Quality of learning experience that students gain in the foundation year of their higher studies is important as the impact of that experience lays the foundation for their learning in the later years and also develops their ability to learn independently. One of the possible strategies to support students in the foundation year is to provide them formative assessments. If these formative assessments are supported with appropriate and timely feedback, they can guide students about what is expected from them. As a result, it will develop confidence within them and can enhance the quality of students' learning experience in the foundation year (Yorke, and Longden, 2004; Nicol, 2006).

Another way of improving students' learning experience is to provide them individual support. It has been proven that students' learning is improved when they receive individual tutoring (Bloom, 1984 as quoted in Desmarais and Baker, 2012). It is difficult to provide individual support in post-secondary education, as there are a large number of students in one class and students get fewer face-to-face sessions with their instructors. The impact of formative assessments can be improved with the help of constructive and instant feedback which is possible with the help of online assessment tools (Dani, 2015). Integration of web-based assessments and learning tools, such as, tutoring systems is an alternative to approach to provide both individual support and frequent formative assessments (McArthur and Stasz, 1990, Miller, 2009).

As a result of adaption of such software systems in teaching and learning the focus of learning is changing from *teacher centered* learning into *student centered* learning as advocated by the constructivist theory. Though this change is promising it also implies that students are expected to develop self-regulatory study abilities (Aleven, Roll, McLaren and Koedinger, 2010; Dani, 2015; Georgia & Symeon, 2010; Nicole, 2006; Razzaq, Mendicino, and Heffernan, 2008).

Though formative assessments, such as, homework assignments are designed to increase motivation and attain mastery of the course content, this formative assessment strategy may not be sufficient for predicting the final grades in the course (Hauk and Segalla, 2005; Trautwein and Köller, 2003; Özcan, 2016). Online assessment tools, also known as web-based assessments tools provide opportunities of distance learning as well as integrate courses from Science, Technology, Engineering and Mathematics (STEM) disciplines (Hauk and Segalla, 2005; Gitsaki and Robby, 2015).

Computer based assessments have several advantages over paper based assessments (Thelwall, 2000). They are available online which means concurrent access is provided to any number of students anytime and anywhere. Moreover, they support a wider range of assessment techniques than the paper based assessments, such as inclusion of graphics and multimedia. Student's responses to the assessment questions can be in the form of numbers and texts as well as in the form of hotspot clicking. A feedback based on the evaluation of a response is given instantly by these systems and such feedback is individualized. More importantly, software can generate questions randomly from a large question bank. Random based assessments not only control malpractices, such as copying and cheating, but also provide ample practice questions required for mastering a topic (Thelwall, 2000). This type of web-based assessment software plays important role in promoting student-centered learning by engaging students in meaningful learning activities and by fostering skills of independent learning (Chen, Yunus, Ali, and Bakar, 2008). Well-designed assessment software, such as Cognitive tutor (Ritter, Anderson, Koedinger, and Corbett, 2007), projects like Mathematics Intervention Module (MIM) have been developed to increase student's engagement in learning mathematics (Shute and Underwood, 2006). These software systems provide students instant feedback on their problem solving attempts.

Nguyen, Chuan and Donald (2006) claim that learning with such web-based assessment systems leads the students to have more control over their work and their efforts as they get the immediate feedback and instant scoring. As a result, the students develop abilities to learn independently. Their success or failure in mathematics learning is related to their efforts and ability to learn independently. Many researchers also found that computer-based or web-based assessment and practice had positive and extraneous effects on students' mathematical learning processes (Hagerty & Smith, 2005; Hauk & Segalla, 2005; Nguyen, Chuan and Donald, 2006)

2.2.2 Integration of technology in mathematics education

In this section, a brief history of practice of using tools in mathematics education is provided. This review sets the rationale for using iPads and other digital tools in mathematics education.

Various tools and technologies, such as log books, simple calculators have been used for effective teaching of mathematics (Maschietto & Trouche, 2010). A graphing calculator was the most popular device used in classrooms in American high schools since 1970 (Trouche, & Drijvers, 2010). Different types of software supported by Computer Algebra System (CAS) which are available on graphing calculators can provide dynamically linked visual multiple representation, simulation and interactive tutorials (Dede, 2008). Due to dynamic linking between different representations, students can see how changes in one form affects the representation in another form.

After the emergence of computers and the Internet technology, e-learning became the most accepted technology in higher education. The term e-learning refers to a learning environment in which computers and the Internet is adapted. In the E-learning environment, the students use their computers within a defined location such as a classroom and within a defined time such as class time.

Advanced software available on desktop computers are important learning tools in a typical e-learning environment. Another important feature of e-learning environment is the communication facility provided by networking. Communication among students and instructors is facilitated through networked computers in a typical e-learning environment (Roschelle,2003). Though desktop and laptop computers facilitate learning through visual multiple representations and allow collaboration, however; they are not portable and lightweight and may not be affordable to all individuals.

The same software, as used on the desktop computers, are now available on handheld computers, which are less expensive than the desktop computers (Roschelle, 2003). E-learning environment required a specific setup, such as, computer laboratory. The teachers had to learn how to use specific software and accordingly they had to change their lesson plan to incorporate skills of using software. In contrast, these handheld devices and supporting technology did not require specific setting or networking, eliminating the need to conduct mathematics classes in computer labs. These devices were easy to use and teachers did not have to alter their teaching lesson plans significantly (Bray & Tangney, 2016).

Mobile devices, such as tablet computers, provide functionalities of graphing calculators as well as provide other sophisticated features, such as *augmented reality*. Through augmented reality interefaces it is possible to superimpose virtual information on physical objects which can be effectively included in linking mathematical world to real life world (Dunleavy, Dede, & Mitchell, 2009; Ke & Hsu, 2015). Graphing calculators have been pre-dominantly used in high schools a decade ago, but they are now being replaced by tablet computers that have larger screens than a graphing calculator and which can run diverse applications concurrently (Fisher, Lucas & Galstyan, 2013; Roschelle, 2003).

According to Jonassen (2003), these digital tools available on handheld devices greatly influence cognitive processes. They act as external cognitive aids. Therefore, these tools can be considered as *cognitive tools*. Jonassen (2003) further argues that it may be difficult for some students to assimilate multiple elements of information simultaneously. The cognitive tools can take their cognitive overload off, as the storage and retrieval of information become easy with the help of such tools.

Trouche and Drijvers (2010) have given four reasons of popularity of these handheld devices, such as graphing calculators. These devices are popular amongst students because they are personal, interactive and they have the features of generating dynamic representations of graphs and data. It is easy for students not only to use the device but also to decide when to use the device. As reported in (Fensom, 2011, Olley, 2011) the teachers could assign the responsibility of its use to students. Since there is no need for additional infrastructure for the use of these handheld devices, it is easy to use them in the assessments, such as in the written examinations (Schneider, Egan & Julian, 2013). Thus ease of use in teaching, support for different representations, ease of use in the formal assessments and the flexibility of adapting them to any classroom settings are the four reasons of popularity of these handheld devices (Berger, 2010; Hitt & Kieran, 2009; Erbas, Ince & Kaya, 2015; Fensom, 2011; Kemp, 2011).

Though it was easy to use these devices, not all teachers had incorporated them in their teaching before the authorities decided to use these devices at the national level assessments. After the change in the national policies, teachers incorporated them in their teaching because they did not want their students to be at disadvantage. Somewhat similar situation is faced by teachers in the federal universities in the UAE. The teachers in these universities adopted iPads in their teaching more rigorously after the iPads were incorporated in the assessments (Gitsaki, Robby, Priest and Hamdan, 2013; Gitsaki & Robby, 2015).

Theoretical aspects of integrating such tools in teaching and learning are presented in the next subsection.

Role of tools in teaching

Johnassen (2003) and Oates (2011) emphasize that digital tools not only take away the burden of complex computation, but also provide opportunity for investigating and developing various problem solving strategies. In the early research about using computers as mathematics learning tool, Goos, Galbraith, Renshaw, & Geiger (2000) established that teachers can use a tool with the purpose of *supporting, or extending* or *transforming* their teaching. They named these three purposes of using a tool as roles of the tool. Each of these roles is described below.

Tool to Support teaching

A teacher can use a tool to make routine mathematical computations easier without altering the course contents and the method of delivering the content. For example, the concept of standard deviation can be explained by the teacher without using any tool but students may be allowed to use a spreadsheet or a calculator to compute standard deviation of a large data set. In this example, a tool is used to *support* teaching.

Tool to Extend teaching

When the teacher alters the course content and also the method of teaching with the help of a tool to facilitate conceptual change, the tool not just supports but *extends* teaching. For example, a teacher can ask students to draw scatter plots of two different data sets using a graphing tool and then estimate the type of correlation between each pair of data sets by comparing and contrasting the graphs. In this case, with the help of a graphing tool students can focus more on constructing knowledge about correlation than spending time on drawing the graphs. The role of a tool in this case is to *extend* teaching. But it should be noted that in such examples, though the content and method of teaching is changed, such tasks can still be learned without a tool. But the tool is included to facilitate construction of new knowledge and foster student-centered learning.

Tool to transform teaching

A tool can be used to perform a more sophisticated role in teaching concepts which are otherwise difficult to teach and learn manually. Mathematical tasks, such as plotting graphs in three dimension or evaluating determinants of an order higher than four, are difficult and time consuming if done manually but these problems are simplified with the help of a digital tool. It is difficult to include such problems in the course content without a digital tool. A tool can transform teaching when it is used to teach such concepts as it can change the contents and method of teaching. With the help of such tools, students are better equipped to model real world problems, which are more often ill-structured problems, as they become easily solvable. Thus the content as well as the method of its delivery can be transformed by including digital tools in teaching mathematics.

Role of Tools in learning

Similar to the variety of tool usage by teachers, students also use a tool in different ways and there are different patterns of tool use in learning mathematics. For example, some students might conform to the instructions form their teacher and use the tool accordingly, while others can use it by exploring the tool for more creative tasks. Geiger (2005) identified four different roles of a tool in learning of mathematics based on the ways students were using them in learning mathematics. These roles are termed as *metaphors* by Geiger (2005).

In some cases, a student may use the tool at the basic operational level as guided by the teacher. She may not able to assess the accuracy or inaccuracy of the result produced by the tool. Then the tool is assuming the role of a master. Geiger (2005) terms this metaphor as *tool as a master.* A student who is using the tool as her master, lacks the knowledge of making a decision about the correctness of the solution provided by the tool. The student may not be able to decide when and how to use the tool. On the other hand, the metaphor *tool as a servant* indicates that student is able to decide when and how to use the tool as well as able to interpret the output. A student, who can interpret the error messages and take corrective actions, is using the tool as her servant. Unlike a student who uses it as a master, the user in this case can decide when and how to use the tool. When a student is proficient in operating the tool and can use it beyond routine problem solving tasks to construct new knowledge, she is using the *tool as a partner*. In spite of having the proficiency and creativity in using the tool, students need to be aware of the fact that the tool is a means of solving problem and not a problem solver itself. When a student knows that any problem needs to be solved cognitively and is able to solve a problem equally confidently with or without a tool, she is using the tool as an *extension of self.*

Beliefs about the nature of mathematics knowledge and how to acquire it are termed as epistemological beliefs (Schommer-Aikins, Duell and Hutter, 2005). It has been found that these beliefs have a considerable influence on student's problem solving ability (Jackson, GGraesser, McNamara,2009; Jansen, DiNapoli, & McKenney, 2017). Earlier research about epistemological beliefs considered four dimensions, which are the structure of knowledge, the source of knowledge, the speed of learning and the ability to learn (Muis, 2004). The instruments used for measurement of these dimensions do not account for learning mathematics with the help of tools, which may be altogether a different dimension. Chiu, Liang & Tsai (2013) developed an instrument to measure epistemological beliefs related to source and acquisition of knowledge in Internet-based learning environment. They propose that inclusion of meta-cognitive activities is vital in the Internet-based learning environment. In the mobile learning environment in the higher education, students are expected to develop sophisticated epistemological beliefs which can be promoted by inclusion of meta-cognitive learning activities.

Tan (2009) and Stewart, Thomas & Hannah, (2005) developed survey instruments to access how students are using graphing calculator as a tool based on the above mentioned framework of metaphors. This instrument will fail to measure how students are using an intelligent tutor as a tool because intelligent tutoring software have more sophisticated computational ability as well as artificial intelligence. Student's ways of interacting with intelligent tutors may be different than the ways of learning with graphing calculators. Therefore, a detailed survey instrument is needed to investigate how students are interacting with an intelligent tutor software.

A brief review of intelligent tutors is given in the next section.

2.2.3 Intelligent tutors

An intelligent tutor system (ITS) is a software system which has four different components necessary for achieving the effect of human-tutoring. The first component is responsible for storing and manipulating the domain knowledge whereas the second one is responsible for storing and retrieving appropriate teaching strategies. The third component is responsible for communicating with the learner and the fourth component is responsible for maintaining information about student knowledge as well as student's learning history. It also has the learning component and the control component (Mark, and Greer, 1993). The efficiency and sophistication of these four components determine the relevance, quality and suitability of the tutor system in education.

Since intelligent tutors are developed with the aim of improving learning outcomes, developers of intelligent tutors work towards achieving the same effect as expert human tutoring effect (Wood, and Wood, 1996, Thelwall,2000). The emergence of web-based technology and artificial intelligence techniques have resulted in the growth and evolution of teaching and learning of mathematics (Nguyen, Hsieh, and Allen, 2006; Chen et al, 2008). Intelligent tutors provide superior performance than any other computer assisted instruction program because they are developed by combining theories of cognitive science and techniques of artificial intelligence (Anderson, Boyle, Corbett, and Lewis,1990; McArthur and Stasz, 1990; Melis and Siekmann, 2004, Xin et al, 2017). These tutoring software systems make personalized tutoring widely and inexpensively available (Woolf et al, 2009 as quoted in Sabo et al, 2013).

Two prominent theoretical frameworks are used in the development of intelligent tutoring systems (Anderson, & Schunn, 2000; Falmagne, Cosyn, Doignon, & Thiéry, 2006). The first framework is known as *adaptive control of thought-rational (ACT-R)* and the second is known as *knowledge space theory*. Both frameworks are described next.

According to the ACT-R theory, complex cognition is composed of relative simple knowledge units (Anderson, & Schunn, 2000). This theory implies that complex concepts can be understood by mastering each of its constituent components and it proposes two distinct types of knowledge as *declarative knowledge* and *procedural knowledge*. Declarative knowledge is the knowledge about facts necessary for problem solving and procedural knowledge represents knowledge about rules of problem solving. Learning is viewed as an incremental process in which a student tries to solve a new problem by making references to past problem solutions. (Anderson, & Schunn, 2000; Sabo et al, 2013).

The Cognitive tutor is an intelligent tutoring software based on the ACT-R theoretical framework (Ritter, Anderson, Koedinger & Corbett, 2007) whereas ALEKS is developed on the theory of knowledge spaces. The theory of knowledge space is not a cognition theory like the theory of ACT-R, but it formulates rules to determine correctness of a student's next response based on his current response. While intelligent tutors like Cognitive tutors are appropriate for novice learners where every step is supported through feedback, use of systems like ALEKS is appropriate in higher education where students are expected to develop the ability to follow through problem solving procedures with minimal support.

A key feature of these software systems is their ability to record and store every learning activity occurring when a student interacts with the system. The data gathered for every user can be analyzed providing *learning profiles* for each student as well as for the whole class. A learning profile is useful to understand student's study habits and her progress (Kotsiantis, Tselios, Filippidi & Komis, 2013). Learning profiles can be detected by applying methods of *Learning Analytics* in which system-generated large data logs are analysed in order to understand students' learning activities (Siemens & Long, 2011). The reports generated with the help of learning analytics techniques support instructors to assess progress of each student and plan remedial actions where necessary.

Techniques of learning analytics focus on deriving information which can reveal how students use the intelligent tutoring systems and identify potential *identifiers* of academic achievement. (Desmarais & Baker, 2012; Kotsiantis, Tselios, Filippidi & Komis, 2013;

Libbrecht, Rebholz, Herding, Müller & Tscheulin, 2012). Application of methods of learning analytics can be a powerful means to inform and support learners, teachers and their institutions to better understand and predict individualized learning needs and performance (Greller & Drachsler, 2012; Siemens & Long, 2011, Tempelaar, 2014). There are specific student attributes which are maintained by these systems, such attributes include *the time spent* on learning and reviewing each topic, the types of interactions and the sequence of activities (Siemens & Long, 2011, Dani 2016). Such system specific attributes are taken into account for analyzing students' learning patterns or their engagement in learning, but in some cases new attributes are derived to gain deeper understanding of determinants of students' learning (Antonenko, Toy & Niederhauser, 2012). In case of analysis of ALEKS data logs, learning analytics indicators can be derived by combining the information about the number of topics practiced, time spent on learning and number of topics mastered. This analysis could provide information about whether a student can learn from the instructional queues and feedback provided by the software and apply them for mastering the course content (Dani, & Nasser, 2016).

2.2.4. Review of empirical studies

Educators in the Western countries have found that the handheld devices supported by CAS can be used for effective teaching of mathematics (Berger, 2010; Hitt & Kieran, 2009; Erbas, Ince & Kaya, 2015; Fensom, 2011; Kemp, 2011; Mayes, 2001; Olley, 2011; Raj 2011). In this section, a review of empirical studies which invesitgated use of tools in teaching mathematics is presented.

Many studies examined the use of graphing calculator together with the computer algebra systems (CAS) and found that these devices improved student's achievement and their learning experience (Hoyles, Noss & Kent, 2004, Lagrange 1999; Lagrange, & Minh, 2010; Pointon & Sangwin 2003; Stewart, Thomas & Hannah 2005; Thomas & Hong, 2004).

Kemp (2011, pg 217) has noted from his teaching experience that the handheld devices help students get intuitive feeling for the mathematics. He further mentions that it is easy to establish links between different branches of mathematics, such as algebra and geometry. These links can be easily explored by students due to visual representation provided by the graphing feature available on handheld devices. Exploration of these links leads to realization that mathematics is not arbitrary collection of abstract ideas but it is a collection of inter-related ideas. Olley (2011, pg 173) also used graphing calculator and created real-life scenario for students. Students worked in groups to solve a real-life problem using mathematical modelling. He reports that students were not just able to learn functions and graphs, but they also learned the process of mathematical modelling. Fenson (2011, pg 205) has demonstrated that these devices are easy to use and they can be used to engage students whose performance in mathematics is either at the average or below average level. He further states that these devices should not be used only for class activities but also should be used for assessments. He claims that it is possible to set assessment questions such that students use the mobile device for solving questions, but the examiner can test the underlying mathematics concept and not just the skill of using the device.

Hampshire Inspection and advisory services, UK reported positive outcomes of using handheld devices for teaching Mathematics in high schools and universities (Taylor, 2011). Their report is based on evaluation of three projects which spanned over 20 years. In these projects, the participating schools and universities used three different technologies, laptops, PDAs and graphing calculators with software for downloading data and printing to teach mathematics for year 11 to 16 (Taylor 2011, pg. 242). One of the important outcome as reported by the author of this report is that they observed positive change in students' sense of responsibility and self-esteem. The author attributes this positive change to the continuous access to the portable equipment, such as PDA and the graphing calculator. He further reports that students became aware of all possible tools, such as the above mentioned devices and software available on them. This awareness developed in students an ability to make informed choices about using the appropriate tool or program to solve any mathematical problem. Along with this critical thinking ability students also developed ability to learn independently. They were able to explore new problems independently and derive their own knowledge. But he points out that students' choice of tools and its application must be monitored and their derived knowledge must be assessed by the teachers. Dede (2008) found that the advanced features available on the mobile devices, such as interfaces supporting augmented reality, can be useful for integrating real-life experiences into learning. All these empirical studies report how the teaching instructions changed due to use of mobile device in teaching mathematics.

Educators found that the handheld devices help students concentrate on the conceptual understanding, and get intuitive feeling for mathematics and establish links between different branches of mathematics, such as algebra and geometry. Students can learn the process of mathematical modelling using hand held devices and their help-seeking practices can be transformed (Aguilar & Puga, 2015; Kemp, 2011; Olley, 2011; Raj, 2011).

The development of mathematical knowledge covers not just understanding of concepts, facts and procedural skills, but also ability to determine appropriate problem solving strategy. Some tutoring systems allow students to write all solutions step by step as if they were solving on paper. Knowledge about different problem solving strategies and ability to decide when and how to use a particular strategy is termed as meta-cognition (Jaafar, Wan, and Ahmad, 2010; Schoenfeld, 1992; Özcan, 2016). Computer supported teaching has been found supportive in developing meta-cognition (Georgia and Symeon,2010). In their recent research (Xin et al, 2017) reported their findings about effectiveness of their specially designed intelligent tutor, which they named as PGBM-COMPS. This is an acronym of *Please Go Bring Me-Conceptual Model-Based Problem Solving.* Their research shows that use of such intelligent tutor can support primary school students who may have learning disability. Learning with online tutoring systems is useful for weaker students, as they receive scaffolding throughout their problem solving sessions (Beal, Walles, Arroyo, & Woolf, 2007).

Although the use of a mobile device has been found useful by many researchers as stated above, other researchers report some limitations of use of these devices. The device itself has limitations, such as small screen size, short battery life and limited interactivity. Other negative aspects of using mobile devices are that it may not always promote deep thinking, students easily get distracted and often tend to do multi-tasking which affects their concentration on the subject matter (Kukulska-Hulme & Pettit, 2009; Handal, MacNish & Petocz, 2013; Aamri & Suleiman, 2011). Potential for unethical behavior, health concerns and data privacy issues are other negative aspects (Pachler, Bachmair & Cook, 2010, p. 9). ICT has a prominent place in students' lives but teachers may not be completely ready to integrate them in their teaching. Many teachers prefer to teach in the same way as they had learned using the traditional method of pen and paper. (Brummelhuis & Kuiper, 2008; Waits & Demana, 2000). Teachers are either not yet convinced about usefulness of the tools or they are not willing to accept this change. Both these barriers are rooted in their limited knowledge about how to use the technology effectively for teaching (Dede, 2008; Lavicza,2007; Lavicza, 2010). Thus to make optimum use of the mobile technology, it is important for teachers to have a framework which can be used for development of content, instructions and assessments and in which congruence will be achieved between the curriculum, pedagogy and assessments (Leigh-Lancaster, 2000).

Though effectiveness of using mobile technology has been confirmed by many researchers (Chien et al, 2008), some researchers also found that if a student believes that a computer can't help them learn (even though they do actually learn), then they have a high probability of disliking the system and becoming less motivated (Jackson, Graesser and McNamara, 2009). It may be necessary to examine the role of non-cognitive factors, such as beliefs and interest. While investigating phenomena of learning mathematics, it is important to understand affective constructs. Persistence, seeking external help and efforts exhibited while interacting with the tool and while solving problems are some of the factors that constitute student's study patterns and these patterns are influenced by psychological constructs, such as affect (Jansen, DiNapoli, & McKenney, 2017). Affect is viewed as a dynamical system which is composed of attitudes, beliefs and values and it can change according to the change in the context (Hannula, 2012). Stewart, Thomas, & Hannah (2005) developed a survey instrument to examine student's instrumental genesis but there are some limitations in their instrument. Their focus is to examine what do students think about using CAS supported calculators and the items are measured on the Likert scale from 1 to 3. Some of the items in their instrument have been adapted in this study after modification of scale. McArthur and Stasz (1989) incorporated some items in their survey instrument to assess student's affect about algebra tutor which have been adapted in this research after some modification.

Theory of *self-regulated learning* postulates that learners are able to set learning goals and they attempt to accomplish them by regulating their actions. It was found that students may enjoy learning with intelligent tutors, but in order to retain the mastery of their learning, they need to organize their learning activities (Dani, 2016).

Male and female students are found to exhibit different behavior patterns in online learning. (Yukselturk and Bulut, 2009). Kaino (2008) found by empirical investigation that girls and boys both agree that computers are useful, but girls had higher anxiety than boys. This study was about use of computers in general. Empirical findings in the context of learning mathematics are reported in (Zualkernan, 2015). The author found that girls and boys did not show any difference in mastering numeric skills using technology.

Gitsaki and Robby (2015) suggest that results from large scale studies provide a broader knowledge base to understand when mobile learning is most useful and what are potential drawbacks and benefits of mobile learning. Their research is in the similar context but their findings are based on analysis of ALEKS data logs only. Also they have examined impact of ALEKS on student's learning in a remedial mathematics course. There are not many empirical studies reporting gender differences in learning with intelligent tutor.

After reviewing success stories of use of iPad and other mobile devices to teach mathematics, there is a room for believing that usings iPads may prove effective in the UAE.

2.5 Summary

Findings from the review of existing literature are summarized below.

Digital tools can demonstrate multiple representation, simplify symbolic manipulation, take off the cognitive burden of complex computation, and allow exploration of different problem solving strategies. Teachers can use a digital tool to support, extend or transform teaching using these features of digital tools. Students can use the tool as a *servant*, or as a *master*, or *as a partner or extension of self* as per their ability to think mathematically Researchers have reported that use of mobile tools in teaching facilitates differentiated, authentic, collaborative and student-centered learning and provides means of visualization of content and concepts (Smith, & Santori, 2015). At the same time some researchers reported that that it does not promote deep thinking, students easily get distracted and often tend to do multi-tasking which affects their concentration on the subject matter (Aamri & Suleiman, 2011; Handal, MacNish & Petocz, 2013; Kukulska-Hulme & Pettit, 2009).

The type of student's interactions with the tool must be examined within a context of learning activity which includes the learning community and the physical and cognitive tools. For appropriate development and deployment of online mathematics assessment and tutorial system it is important to assess students' expectations and attitude about the software. Extensive research has been done on use of graphing calculator as a mathematics learning tool (Berger, 2010; Hitt & Kieran, 2009; Erbas, Ince & Kaya, 2015; Fensom, 2011; Kemp, 2011; Mayes, 2001; Olley, 2011). There is a need to do a similar research on use of an intelligent tutor to teach and learn mathematics.

This research will attempt to fill this gap by examining the current practices of using an intelligent tutor and exploring the student's patterns of interaction with the intelligent tutor. Also the existing research literature reports results on student population from western countries. Whereas, the current research is done by collecting data from a population of university students in the United Arab Emirates. Research about using mobile devices for mathematics education in this context will lay foundation for development of appropriate tools, curriculum and pedagogy suitable for similar context.

3. Research Methodology

This chapter describes research approach, rationale for research design and the descriptions of all stages of the study designs for addressing the four research questions.

3.1 Research approach

As described by Cohen, Manion, and Morrison, (2011, pg. 41), the research which aims to understand users' expience, fits into the interpretivist research framework. The current research aims to understand students' mobile learning experience, hence it follows the interpretivist research framwork.

Qualitative, quantitative and mixed-method are three research approaches. When the data is collected in the form of text or observations of an ongoing process carried out in naturalistic setting, the qualitative research approach is recommended (Creswell, 2008, p.55). On the other hand when, the data is collected in numeric form, the quantitative approach is recommended (Creswell, 2008, p. 55). Qualitative research approach is adopted for understanding the depth of some social phenomena whereas quantiative approach is adapted for understanding the breadth of social phenomena and for making some kind of prediction about success or failure related to that phenomena. The crucial distinction between these approaches is that the qualitative approach is case oriented and the quantitative approach is variable oriented. The research which aims to explore a social phenomenon is termed as an exploratory research for which the qualitative research approach is recommended. The research which aims to make some kind of predictaion about the success or failure of a social phenomena is explanatory, for which the quantitative approach is recommended (Punch, 2009, p. 292).

Just one of the two approaches, quantitative and qualitative, may not always be sufficient for attaining the research aim. In that case a mixed method approach is more apporpriate. In the mixed method research “the investigator collects and analyzes data, integrates findings, and draws inferences using both qualitative and quantitative approaches and methods in a single study or program of inquiry” (Tashakkori and Creswell, 2007, p. 4) quoted in Teddlie and Sammons (2010).

The current research has two components as shown in the Table 3.1. The first component aims at understanding mobile learning activity and perceptions about the intelligent tutor from a large sample of students and teachers. Based on these findings it further aims at predicting which of these activities may enhance the student’s learning experience. Whereas, the second component aims at understanding mobile learning activities taking place inside mathematics classrooms. Since the first component attempts to investigate the breadth of the mobile learning, it is researched quantitatively. The second component aims to inestigate the depth of the mobile learning, it is researched qualitatively. Thus a mixed method research approach is appropriate for the current research aim.

Table 3.1: Statements of research questions and chosen approach for each

Research approach	Research question	Data collection method	Target population
Quantitative	RQ1: How do students perceive suitability of iPads with approporiate software (such as ALEKS), to learn mathematics?	Survey	Students
	RQ2: How are students using iPads and interacting with ALEKS in the classroom and outside the classroom?	Survey and ALEKS data logs	Students
	RQ3: Since the introduction of the iPad initiative, upto what extent are iPads being used to teach mathematics in the chosen institute?	Survey	Teachers
Qualitative	RQ4: What type of interactions occur in the classroom where iPads and other digital tools are used for teaching mathematics?	Observation	Students and teachers in the mathematics course classroom

The first three research questions are addressed using quantitative research approach and the fourth research question is addressed using qualitative approach. The quantitative data was collected using surveys from two samples, one for teachers and the second for students.

Qualitative data was collected after collecting quantitative data from the teacher survey. The qualitative data from observations and quantitative data from student surveys were collected in parallel. The purpose of adapting mixed method research approach is to gain understanding of two different phenomena, hence the research deign is *convergent parallel* mixed-method design (Creswell, 2008, pg. 557). As it can be seen from the Table 3.1, the major component of this study is addressed using quantitative research approach, hence the quantitative component has a higher weighting than the qualitative component.

The data collected from the two research questions RQ1 and RQ2 will reveal students' perceptions about ALEKS and their study habits. The research aims to predict the impact of their perceptions and study habits on their learning experience as well as their learning outcome.

3.2 Research design

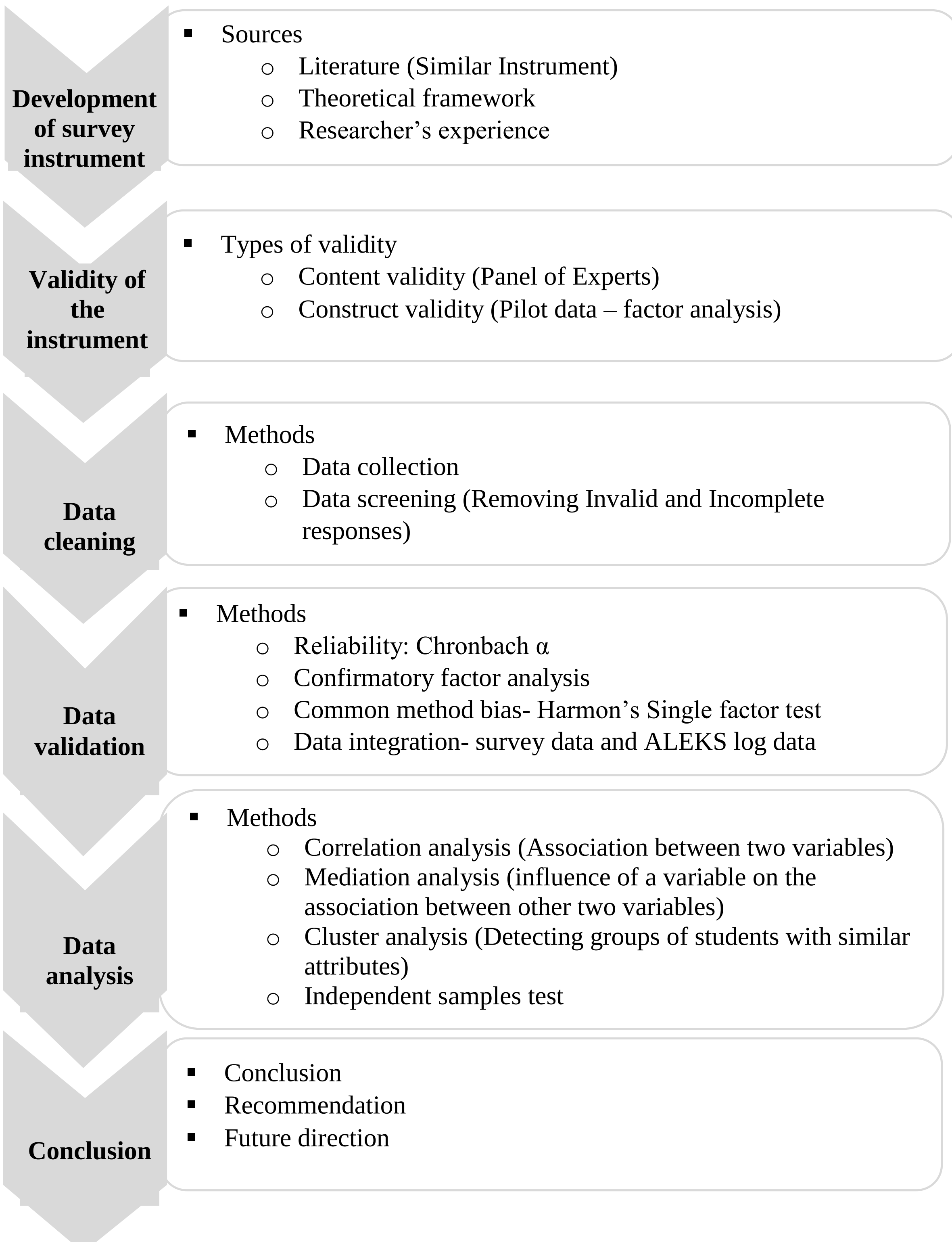
For research studies which aim to establish effectiveness of some innovative approach, such as a new teaching method using digital tools, quasi-experimental design is recommended (Creswell 2008, pg. 312-314). In the quasi-experimental design, control and treatment groups are formed and then the proposed new method is adopted for teaching students in the treatment group only. In the chosen research context, tablet-based teaching using the intelligent tutor ALEKS is mandatory for all students. Adhering to the institution's policy, it was not permitted to form control groups (without iPad and ALEKS) and treatment groups (with iPad and ALEKS). Consequently, quasi-experimental research design was not feasible, instead a cross-sectional field survey method is applied to address research questions 1 to 3. As guided by the theoretical framework of Activity theory, the research question 4 is examined by observing classroom activities.

The description of research design adapted for the survey method and observation method is provided in sections 3.3 and 3.13 respectively. The first four stages of study design related to research methodology are discussed in this chapter and the remaining stages related to data analysis are discussed in the next chapter. At the time when this research was carried out there was no similar research done about learning mathematics with intelligent tutors. Therefore, a new survey instrument was needed to measure perceptions and ways of interacting with the chosen intelligent tutor. In the current research methodology all stages of development and validation of a survey instrument are covered for both the student and the teacher surveys.

3.3 Study design

Figure 3.1 shows all stages of the study design adapted for the quantitative part

Figure 3.1: Study Design



Description of execution of each step is given in following subsections.

3.4 Student survey- development and validation

The survey method is appropriate to capture a snapshot of current teaching and learning practices and to measure a large number of variables from a big sample (Creswell, 2008 p. -225). Field survey method has strong *external validity*, which means that there is a possibility of generalizing results observed from one organization to other organizations in similar context. (Bhattacherjee, 2012 p.-36; Creswell, 2008 p.225). But it may lack *internal validity* because the dependent and independent variables are measured at the same time frame and there is no manipulation and control of variables or no treatment involved. Another drawback of this method is *respondent biases,* which are caused when respondents provide ideal responses rather than true responses. Though it may not be possible to eliminate this bias completely, efforts were made to ensure that students provide their true responses. In order to reduce respondent bias, the survey instrument was designed and presented in a user-friendly format. All survey items were presented in Arabic and the survey length was kept minimum. The students were assured that their responses would not affect their coursework marks. They were also assured that the collected data would be used to improve their learning experience.

Common method bias is another threat to the validity of conclusions based on the data measured by a survey instrument. It is caused due to measurement error which can occur due to a common medium used for measurement of all variables. In order to avoid this type of bias, variables are measured from two sources, one source is the surveys and the other source is the data logs generated by ALEKS. Also the *Harmon's single factor test* is applied to ensure that the survey instrument is free from the common method bias. (Bhattacherjee, 2012 p.-82). The detail process of development and validation of survey instruments is described in the next section.

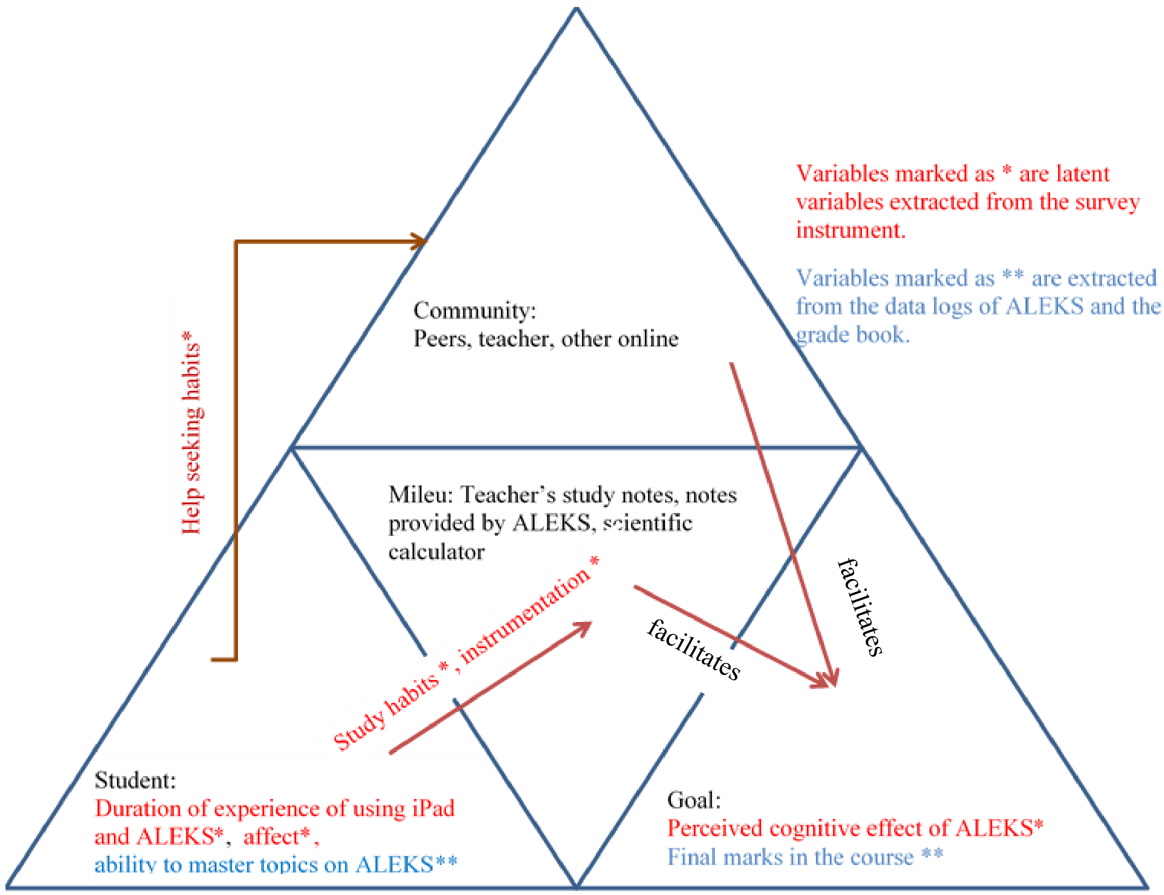
The *student survey instrument* is required to address a major component of this study. It is designed to measure necessary variables required to address research question 1 and 2 on the basis of the theoretical framework described in chapter 2. In its development, first a conceptual framework is derived from the theoretical framework, which is described in the next subsection.

3.4.1 Conceptual framework for student survey

A carefully developed conceptual framework defines relevant concepts, establishes theoretical and empirical rationale, guides selection of appropriate methods, and also scaffold data analysis and interpretation. Conceptual framework is developed by combining all key components of the research processes, literature, theory, methods, and interpretation of findings and is augmented by empirical observations (Antonenko, 2015).

Elements of the two theories, theory of instrumentation and Activity Theory are used as the basis for developing a *conceptual framework* of this study, which are illustrated in the Figure 3.2 and explained in the following subsections.

Figure 3.2: Conceptual model



3.4.2 Components of the conceptual framework

The above framework shows three main components and interactions among them. The components of the activity under investigation are *student* (Subject of the activity), *tool* as well as other resources which form the community *and goal of the activity*. The survey items are designed to measure attributes of these components. The detail process of survey development is described next.

The attributes describing a student as an entity are classified into two categories. The first is the category of demographic attributes and the second is non-demographic attributes. Two demographic variables are included: first is the *gender* and the other variable is the *course of study*. The second variable measures the duration of using ALEKS as measured in number of cycles. One cycle runs for 8 weeks. The students who are enrolled in the first course (M010) get exposure to ALEKS for 8 weeks, students in M020 get exposure for 16 weeks and M030 students use ALEKS for 24 weeks. Students who are enrolled in M010 have less experience of using ALEKS than the students enrolled in the other two advanced courses M020 and M030.

As supported by the theory of instrumentation, student's instrumental genesis process matures with the time spent on using the tool, which implies that students in the second and third course may be more proficient in using ALEKS than those in the first course. Thus the variable course number can be used to assess the development of instrumental genesis over a time period.

According to the basis of theory of instrumentation, it is hypothesized that the proficiency of using a tool and the development of mathematics knowledge influence each other. In order to understand the effect of instrumentation, student's proficiency of using the tool and their development of underlying mathematics concepts explained by the tool are investigated. Some items in the survey are designed to measure these two factors representing *skills of using ALEKS* and *understanding of mathematics.* The skills of using ALEKS are measured by assessing students' perceived ease of using ALEKS and the effect of its tutoring on their learning. Whereas understanding of mathematics is measured by assessing their perceptions about learning.

The student survey instrument also consists of items which measure students' preferences as well as perceived effects of using mobile devices and other learning resources. Some items of the survey are identified on the basis of students' study habits observed by the researcher in class while teaching the course over the past four semesters. The intelligent tutoring software ALEKS provides two-fold support in learning mathematics; explaining mathematical concepts and tutoring support to master the concepts. Some items in the survey instrument are defined to measure students' perceptions about these two features of ALEKS. Effectiveness of ALEKS as a tool which develops understanding of mathematical concepts is termed as its *cognitive effect* while its effectiveness as a tool that provides tutoring support is termed as its *tutoring effect.*

Though the current generation of students has sufficient exposure to technology, one cannot extrapolate that they prefer to learn with computers. Some items in the instrument are adapted from (McArthur and Stasz, 1989) to measure their willingness to learn with computers.

In addition to the above factors, attributes from the data logs of ALEKS, such as *time spent on ALEKS, number of topics practiced and number of topics mastered*, are taken into consideration. The level of student's actual learning efforts with ALEKS are measured from the variables from ALEKS data logs. A detail description of these ALEKS variables is given Table 3.2.

The goal of a learning activity using ALEKS is to develop understanding of mathematics. This goal is also measured at two different levels. The first is measurement of perceived understanding and the second is measurement of actual attainment. Perceived understanding is measured through survey questions whereas actual attainment is measured through marks in course assessment components.

In addition to the chosen tool ALEKS, students are allowed to use other external tools such as a scientific calculator and other apps or websites and YouTube videos. These tools are supporting in student's learning. The *milieu* in the learning activity includes notes provided by teachers, explanation provided by ALEKS, other web-based learning resources, such as YouTube videos and apps like *Geometry Pad*. As advocated by the Activity theory framework, the association between the subject and the tool is mediated by the learning community, which includes peers, teachers and other resources available on the web. Some items in the survey measure frequency of students' interactions with the milieu and the community.

3.4.3 Interactions among the components

As noted above, the chosen theoretical framework implies that learning process is mediated by other resources and the interactions with the learning community and milieu. In this context, it is aimed to investigate which types of interactions improve students' learning experience. Students' beliefs and attitudes about ALEKS are measured as perceptions whereas student's ways of interacting with ALEKS and with peers are measured as study habits.

A tool can be used in four different ways as described in chapter 2. Thomas & Hong (2004) have classified the usage of a tool in different types of tasks according to their purposes as follows. The first purpose of using a tool can be completion of a simple or a complex procedure, second purpose can be reduction of cognitive load and the third can be investigation of a concept. Accordingly, the tool is used as a master, servant or partner for each type of task respectively. Students are expected to be aware of the strength and limitations of ALEKS as well as other tools in completing each of type of tasks. Further they should be able to decide when and how to carry out the above types of tasks with the help of ALEKS and other necessary tools. Some items in the survey are designed to assess if students are using tools purposefully.

Some questions are constructed as new and some are adapted from other similar survey instruments. Questions adapted from other instruments are modified to suit the research context which is learning of mathematics with iPads and ALEKS. The survey instrument consists of two demographic questions, 44 closed-ended questions and one open-ended question. In addition to two demographic questions, student identification number is required to integrate the data from the surveys and the data from the log files of ALEKS.

In the Table 3.2, details of all construct variables are listed.

Table 3.2: Variables measuring students' interactions with ALEKS and with community

Description of the variable	Label	Variable name
Up to what extent the tool ALEKS is effective as a facilitator of learning?	Perceptions about tutoring effect of ALEKS	Factor1
Effectiveness of ALEKS in developing interest in mathematics and its usability.	Perceptions about usability of ALEKS and its effect on interest in mathematics	Factor 2
Up to what extent the tool ALEKS is effective in developing knowledge of mathematics?	Perceptions about cognitive effect of ALEKS	Factor3
In general, what do students think about using digital tools to learn mathematics?	Perceptions about use of computer tools in learning mathematics	Factor 4
What do students think about how to learn mathematics using ALEKS?	Beliefs about learning mathematics using ALEKS	Factor 5
How often they organize their learning tasks and are actively engaged in learning?	Systematic study habits	SHabit1
How often they seek help from source other than ALEKS?	External help	SHabit2
How often they interact with the tool in a systematic manner?	systematic use of tool (ALEKS)	SHabit3
How do they cope with the failure?	Persistence	SHabit4

How often they stay focused on learning mathematics while using iPads?	Distractions	SHabit5
Variables measured from ALEKS data logs		
How many topics has a student attempted to master?	Number of topics practiced	Practiced
How many topics has a student mastered successfully?	Number of topics mastered	Mastered
What is the level of actual efforts of mastering topics and learning with ALEKS?	Ratio of $\frac{Mastered}{practiced}$	mtop
Students' academic achievement (dependent variable)	Total number of topics mastered and retained at the end of the course	AleksScore
	Final exam marks	ExitExamMarks

There are two parts within the section of closed ended questions. Part -1 consists of 29 items about perceptions on the scale from 1 to 5. (1 indicates *Strongly agree, 2: agree, 3: Neutral, 4: disagree* and 5: *Strongly disagree*). Part-2 consists of 15 items about students' study habits and preferences, which are measured on the scale from 1 to 5. (1: *Always, 2: Very often, 3: Sometimes, 4: Very rarely,*5: *Never*).

3.4.4 **Data validation**

Validity and reliability are important quality measures of a quantitative research. Validity of an instrument must be assesed to ensure that it measures what it intends to measure and reliability of an instrument must be assessed to measures its consistency and replicability

(Cohen, Manion, and Morrison, 2011, pg. 179,199). The tests of reliability and validity analysis are carried out to ensure the quality of both the survey instruments.

Content validity of a survey instrument refers to the correct alignment between the latent concepts to be measured and the intended expression of survey items (Muijs, 2010). The content validity of the student survey instruments was checked by a panel of three experts. Two experts were mathematics faculty from the same institute and the third expert was an experienced researcher from another institute. All three experts suggested minor changes in the presentation of the instrument and certified that the survey items had desired content validity.

Construct validity of an instrument ensures that the items used to measure a given construct actually measure that specific construct and do not overlap with other constructs. As recommended by (Bhattacherjee, 2012; Mat Roni, 2014) construct validity of the instrument was checked and confirmed by applying the methods of factor analysis on the pilot data.

3.5 Pilot testing

Pilot testing of a questionnaire is done for two reasons. The first is to check the clarity of items and to check if the target participants can understand them. The focus of such pilot testing is not on the data but the format and presentation of items. The second reason is to gain understanding about the reliability of the instrument (Cohen, Manion, and Morrison, 2011, pg. 402). In this research, a pilot research was carried out to gain understanding of both the format of survey questions as well as the reliability of the instrument.

As noted before, the survey instrument for students was translated into Arabic. The translated version was checked by three faculty members who were fluent in both Arabic and English languages. The accuracy of translation was confirmed by these faculty members. Pilot data was collected from one section (22 students) from one of the 17 campuses of the institute. These were paper based surveys and they were administered in the presence of the faculty to ensure accurate completion of surveys. There were no difficulties reported by participants in completing the survey, hence no changes were required in the content and presentation of the survey instrument. In the next stage of the study, actual data was collected. Description of data collection, screening and validation of collected data is provided next.

Rather than surveying a random sample of students, surveys were sent to four campuses of one institute in the UAE. One campus has all female students and three other campuses have all male students. Thus a convenience but at the same time maximum-variation sampling method was used, which ensured on-time collection of data and representation of both genders (Cohen, Manion, and Morrison, 2011, pg. 157). At the time of the survey there were approximately 800 students enrolled in the foundation mathematics courses. A total 204 students completed the survey. This represents approximately 25% of the target population. Some surveys were administered on paper by teachers in their respective classes while other surveys were sent electronically. The paper based survey administration reported 100% response rate and the electronic survey had 80% response rate. All surveys were administered one week prior to the end of semester, in May 2016, which means students from all courses, including M010, had enough exposure to ALEKS and iPad usage. Also, at that time, sufficient details of learning activities were recorded on ALEKS.

Prior to encoding data, all survey forms were screened carefully. Incomplete survey forms were excluded. Some of the questions in the survey are negatively worded. The forms, in which participants had selected either the left-most column or the right most columns for all items, were considered as invalid as such responses indicate that the participant might have responded without reading each item carefully. Out of 204, participants, 3 forms were excluded after screening. Negatively worded items were recoded to make them consistent with other items. All responses were recorded in SPSS (24.0).

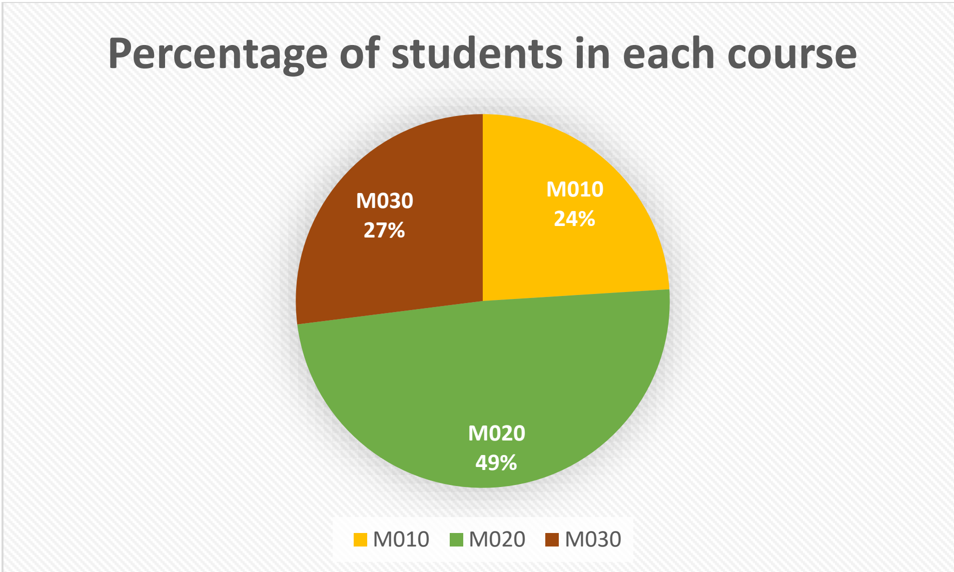
3.6 Description of the student sample

All participating students are learning English as their second language and majority of them are exposed to English medium of instruction for the first time. Out of 201 students 136 are females (68%) and 65 are males (32%). The approximate proportion of female and male students in target population is 3:1. The proportion in the sample is consistent with the population proportion.

In addition to a demographic variable gender, course number is the second demographic variable in the students' survey. 24% participants were enrolled in the first course (M010), 49% in the second course (M020) and remaining 27% in the third course (M030). Only 24% of students had exposure to ALEKS for 8 weeks. The remaining students had used ALEKS to learn mathematics for at least 16 weeks. It can be argued that all students had used ALEKS over a longer period and were in a position to judge its various aspects.

Refer to the Figure 3.3.

Figure 3.3: Distribution of students, according to the course



3.7 Reliability of the student survey

Reliability of the student survey instrument was checked using SPSS. The reliability score Cronbach alpha was found 0.9 for both parts of the survey instrument, which indicates a very high reliability. The scores of Cronbach's alpha on observed values and on the standardized items were found to be equal, which indicates that the instrument has high internal consistency (Bhattacherjee, 2012; Mat Roni, 2014).

3.8 Sample size adequacy

The Kaiser-Meyer-Olkin (KMO) test was applied to test the sampling adequacy and to test the sphericity on 29 items from part 1 and 15 items from part 2, separately. The value of the KMO index ranges from 0 to 1. A sample size with KMO index 0.50 or higher is considered adequate for performing factor analysis. The KMO index is found to be equal to 0.92 and 0.75 respectively for part-1 and part-2 of the instrument (Williams, Brown, & Onsman, 2012, Mat Roni, 2014).

The Bartlett's Test of Sphericity should be significant ($p<.05$) for factor analysis to be suitable (Williams, Brown, & Onsman, 2012, Mat Roni, 2014). Both parts of the instrument showed the significance of this statistic equal to zero. From this statistic, it can be concluded that sample size is adequate and further factor analysis can be applied to this sample.

Harmon’s single - factor test was applied to confirm that there is no common method bias error in the survey instrument (Mat Roni, 2014). According to this statistical test, all variables are loaded into one factor. Then the % of variance of the highest loading item is checked. If this percent variance is less than 50%, then it can be concluded that the instrument is free from the common method bias. All variables from part 1 (about attitudes) were loaded into one factor and all variables from the part 2 (study habits) were loaded into one factor separately. The values of % variance of the highest loading factors for part-1 and part-2 are 34% and 24% (respectively) which confirms that there is no threat of common method bias in the survey instrument.

The results of reliability analysis and factor analysis are summarized in the Table A1-2 in the Appendix -1.

3.9. Factor Analysis

In following subsections, details of exploratory and confirmatory factor analyses of the students’ survey instrument are presented.

3.9.1 Exploratory factor analysis

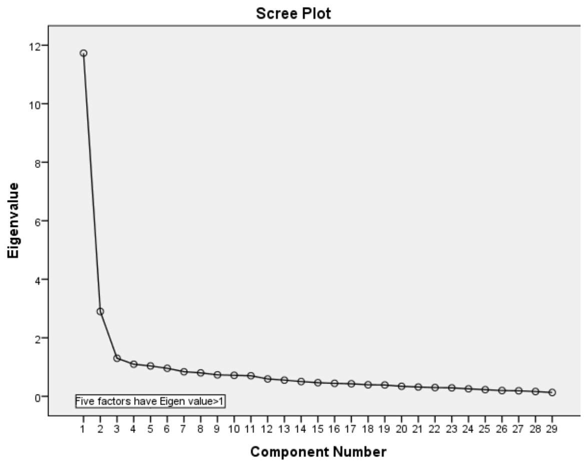
Factor analysis groups number of variables such that each group is homogeneous and distinct from other groups (Cohen, Manion, and Morrison, 2011, page 678). Since many of the items in the students’ survey instrument are either modified or new items, none of the factors are known apriori. When the factors are not known apriori, exploratory factor analysis is recommended (Cohen, Manion, and Morrison, 2011, page 675, Williams, Brown and Onsman, 2012). For exploring the structure of factors, the method of principal component analysis was applied to items in part-1 and part-2 separately. The factors were extracted by setting an Eigen value>1 and minimum factor loading score of 0.4. The extracted factors were rotated using Vari-max rotation method. All items in each part were loaded with a factor loading score more than 0.4, which indicates a good fit (Cohen, Manion, and Morrison, 2011, page 681). The cumulative variance explained by all five factors in part-1 is 62%. All items in part-2 were loaded into four factors and the cumulative variance explained by all four factors in part-2 is 53%. These two figures of cumulative variance indicate that moderate amount of explanatory power is exhibited by those five factors.

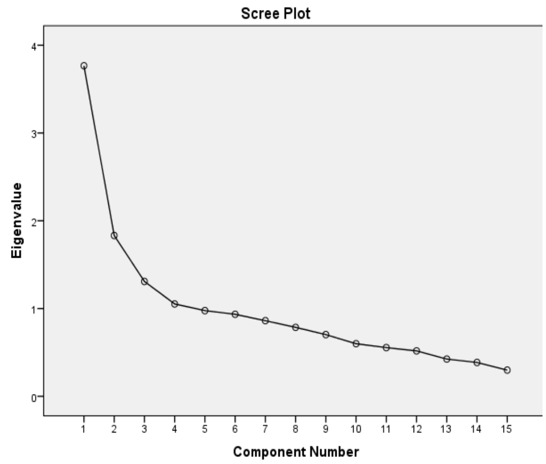
Refer to the scree-plot shown Figure 3.4. (Complete output given in the appendix).

Both the scree plots indicate that the first five factors in part-1 and four factors in part-2 are above the bend in the scree plot and it confirms the inclusion of these factors in the further analysis (Cohen, Manion, and Morrison, 2011, page 677).

Figure 3.4: Scree plots showing number of factors loaded during exploratory factor analysis

Perceptions: Items in Part-1	**Study Habits**: Items in part-2
Loaded into 5 factors	Loaded into 5 factors
Cumulative variance explained: 62%	Cumulative variance explained: 53%





3.9.2 Confirmatory factor analysis

After the exploratory factor analysis, it was found that the majority of the items was loaded into factor 1 (13 out of 29). These items are intended to measure two different variables: *how good is ALEKS as a tutor* and *how effective it is in developing mathematics knowledge.* Therefore, confirmatory factor analysis was required to separate these items into two factors. These 13 items were loaded into two factors by setting the option of *Extract fixed number of factors* using SPSS software. As a result, seven items were loaded into one factor and six items were loaded into the second factor. Their reliability scores were examined separately to confirm their internal consistency.

As a result of the exploratory factor analysis, four factors were extracted from 15 items in the part-2, each showing the Eigen value>1. But it was found that the fifth factor shows Eigen value equal to 0.976, which is very close to 1. Hence, during the next stage of confirmatory factor analysis, five factors were extracted, by setting the option of *Extract fixed number of factors* using SPSS software. After extracting five factors cumulative variance increased from

53% to 60%, so it is reasonable and justified to extract five factors instead of four factors from 15 items in the part-2.

The factor loading scores of these items were examined by loading each set of items into one factor separately and then reliability score for each factor was examined. Item 5, 6 and 14 from the part-2, were loaded into one factor, but their composite reliability score was less than 0.5, which could be increased by removing item number 14 from the factor. The item numbered 14 was left as a single item factor since it always showed a high factor loading.

It was found that each item is loaded into at least one of the factors or one of the study habits, which shows that the instrument has a high construct validity. The details of each factor and study habit are described next.

The five factors in the part-1 are as follows. The first factor measures student's perceptions about *tutoring effect of ALEKS* which combines seven items with a reliability score 0.89. The minimum factor loading score for items in this factor is equal to 0.75. The second factor combines four items, each with a factor loading score higher than 0.58 and their reliability score is 0.79. This factor measures student's perceptions about the usability of ALEKS and its impact on their interest in mathematics. This factor is labelled as *Affect*. The third factor is labelled as *Cognitive effect of ALEKS*. It includes items, such as, *ALEKS helps me improve my understanding of mathematics problems.* It combines six items with a minimum factor loading score equal to 0.7 and reliability score equal to 0.67. Another six items with a factor loading score 0.65 or higher are loaded into the fourth factor, which measures student's perceptions about the use of any computer tool in learning mathematics. The last factor measures their beliefs about learning practices using ALEKS and other tools. It is composed of six items for which the minimum factor loading score is 0.6 and the composite reliability is 0.68.

The five factors representing different study habits in the part-2 are as follows. The first study habit measures how often students study systematically. For example, it includes items such as, *how often they solve a problem step by step*. There are five items loaded in this study habit with factor loading score 0.6 or higher and their reliability score is 0.68. The second study habit has three items which measure their patterns of seeking help from external sources, such as YouTube videos. Each item in this factor is loaded with a factor loading score 0.5 or higher and their reliability score is 0.64. Similarly, the next study habit has the reliability score equal to 0.66 and it has four items. The factor loading score for each of these four items is 0.6 or higher. The items in this factor measure students' ways of interacting with ALEKS. The fourth study habit measures student's ways of coping with failure which is labelled as *Persistence*. It combines two items with a factor loading scores 0.7 and 0.8. The composite reliability score of the items in this factor is equal to 0.72. The last study habit has only one item that measures how often students get distracted while studying, which is labelled as *Distraction*.

A summary of each factor, number of its constituent items, minimum factor loading score and reliability score is given in the Table 3.3.

Table 3.3: Summary of factors and their reliability scores- student survey

Factor name	Number of items	Minimum factor loading score	Reliability score
Tutoring effect of ALEKS	7	0.75	0.89
Affect	4	0.58	0.79
Cognitive effect of ALEKS	6	0.68	0.67
Use of computer tools in general	6	0.65	0.68
Beliefs about learning with digital tools	6	0.58	0.68
Systematics study habits	5	0.60	0.68
External help	3	0.52	0.64
Systematic use of ALEKS	4	0.60	0.66
Persistence	2	0.70	0.72
Distraction	1		

Multiple components of each factor are aggregated to represent the factor's composite score. Such aggregates provide a single numerical score or value representing that factor (Bhattacherjee,2012, pg 52). Accordingly, the mean scores for each factor and study habit were computed. Kolmogorov-Smirnov test was applied on the variables representing these mean scores to test their normality. A variable is distributed normally if the p-value shown by the Kolmogorov-Smirnov test of normality is higher than 0.05. It is found that none of the variables is normally distributed (Refer to the Tables A3-12 and A3-13 in Appendix-3). The deviation of all variables from normality implies that non-parametric tests should be applied for testing all hypotheses involving these variables.

3.10 Data integration

From the data logs maintained by ALEKS, the data about the following variables was extracted: student number, total time spent, number of topics attempted, number of topics mastered, CT (Comprehensive test) score, and final exam marks. This data was integrated with the data from students' surveys by matching the student numbers.

3.11 Teacher survey- development and validation

The teacher survey instrument aims to examine how teachers are using iPads to teach mathematics. This instrument is designed on the basis on findings in the literature. All stages in the development and validation of this instrument is provided in the following subsections.

3.11.1 Survey design

Some items in this survey are designed to measure teachers' perceptions about advantages and limitations of tablet computers and other technology in teaching mathematics. These items are guided by the findings from the review of empirical studies as summarized in chapter 2.

Integrating iPads and ALEKS into a mathematics classroom is mandatory according to the institute's policy. In the early investigation, (Gitsaki and Robby, 2015) found that the teachers from the same institute have positive attitude about integrating iPads in teaching. But Gitsaki and Robby (2015) did not investigate how the iPads are being actually used by teachers for teaching mathematics. The patterns and extent of usage of mobile technology for teaching mathematics may not be uniform among all teachers. The current research examines the patterns and extent of technology usage and also captures the variations within. In the survey for teachers, some survey items are designed to measure the teachers' patterns and extent of usage of iPads in different types of tasks as well as their preferences for assigning roles to these tools as discussed in chapter 2. The design of survey items is adapted from a widely established survey designed by Becker & Anderson (1998), but the questions are redesigned to focus on iPad as a tool used for teaching mathematics.

Likert scale questions on the scale of 1 to 5, are designed to measure perceptions (1 indicates *Strongly disagree, 2: Disagree, 3: Neutral, 4: Agree* and 5 indicates *Strongly agree*) and frequency of using iPad for various tasks (1: *Always, 2: Very often, 3: Sometimes, 4:Very rarely,*5: *Never*). In addition to these questions, teachers are asked to assign a preferred rank to different iPad based tasks according to their importance and then they are asked to report how frequently they implement each of these iPad based teaching tasks. Analyzing the responses in these two survey sections simultaneously will lead to discovery of gap between the intended use and actual use.

Lavicza (2007) found that integration of technology in teaching undergraduate mathematics is influenced by teachers' beliefs about mathematics and technology. In an attempt to explore these beliefs, a survey item is designed in which teachers report their preferred way of integrating technology to teach each of the topics included in the courses they are currently teaching. This was a closed ended question with a Likert scale of 1 to 4 as follows: 1: *No* use of any digital tool[1]; 2: *moderate* use of some digital tool; 3: *high* use of digital tool; 4: Complete adoption of a digital tool.

[1] A digital tool is some app or a web-based software which is delivered on tablet computer

Two open ended questions were included to explore which apps are being used by teachers specific to certain topics and what are their view about teaching mathematics with digital tools.

The next stage in the study design presented in the Figure 3.1 is data validation, which is described next.

3.11.2 Validity of the teacher's survey

The instrument designed for collecting teachers' responses was validated by a panel of four experts. The panel of experts included two teachers who are currently teaching the foundation mathematics courses and two other are expert researchers. They all confirmed the content validity of the instrument. After running a pilot test, some items from part-IV were reworded to make them more precise.

There were no incomplete or invalid responses. Reliability analysis revealed a high score for Cronbach's alpha on both standardized and non-standardized items. (0.8 for each), which indicates that the instrument has high reliability, internal consistency and construct validity (Bhattacherjee, 2012; Mat Roni, 2014).

At the time of data collection, the target population of mathematics teachers in the foundation program of the chosen institute included of 26 teachers from different nationalities and with diverse experience of using technology to teach mathematics at post-secondary level. They all were contacted for participation in the survey, 19 teachers responded, which shows that the response rate was at 73%. One possible reason of non-response is the hectic teaching schedule followed by summer holidays. Since the teachers' data was used for exploration and the major focus of this research is on students' views, the researcher decided to proceed with data analysis of this small sample.

In the teacher's survey, *Gender and years of experience using technology* are the two demographic variables. 32% teachers from the sample are female and 68% male. 21% teachers had less than two years of experience of teaching mathematics using some digital tool. Though 21% teachers reported that they had less than two years teaching experience using some digital tool, it is known from their employment history that they have several years of teaching experience. 42% teachers have been using some kind of digital tool to teach mathematics and remaining 37% had more than five years of experience of teaching with digital tools. The data included cases from both genders as well as cases from diverse experience levels. It can be concluded that though it is a purposive sample, it met the criteria of maximum variation.

The variable gender is included for descriptive study only and there is no further investigation required about gender specific preferences of using digital tools in teaching mathematics.

3.12 Reliability of the teacher's survey

Though the sample is a small sample, adequacy of the sample was tested on each part of the survey separately. The value of KMO measure of sampling adequacy statistics was found to be 0.6, 0.7 and 0.65 for items in part I, II and II respectively and p-value for Bartlett's test of sphericity was 0.0 in each case, which indicates that it is feasible to perform further factor analysis. Two factors were extracted from part-1 and part -2 each. Each item is loaded into exactly one factor with a factor loading score 0.7 and above. Items in the part-3 are not expected to form homogeneous groups, therefore factor analysis was not performed on those items.

Items in the part-1 are designed to measure teacher's usage of tablets or iPads for administrative and teaching tasks. Teachers responded about how often they use iPads for tasks like marking attendance. Four items were loaded into one factor related to use of iPad for *administrative tasks* and six items were loaded into the second factor of use of iPad for *teaching tasks*. Reliability score for the items in each of these two factors was 0.95 and 0.84 respectively. Each item loaded into exactly one of the two factors with factor loading score 0.79 or higher.

Items in the part-2 are designed to measure teacher's perceptions about benefits and limitations of tablet devices as teaching tools. Four items measured perceptions about benefits whereas six items measured perceptions about limitations of these devices. Items in both factors exhibited high reliability (Cronbach α=0.87 and 0.86 respectively). Factor loading score of each item loaded into the factor measuring benefits was 0.83 or higher and for the factor of limitation each item was loaded with factor loading score 0.52 or higher. All six items in part-3 exhibited high consistency (Cronbach α=0.81 and factor loading score 0.57 or higher). They were retained in one factor as each of these items measures actual use of iPads for teaching. It can be concluded that this instrument also demonstrates high internal consistency and construct validity.

A detail description of the survey instrument, including the factor loading scores and reliability scores, is given in Table A1-3 in the Appendix 1.

3.13 Qualitative study design

As described in chapter 1, the research question RQ4, is *What types of interactions occur in the classroom where iPads are used for teaching mathematics?* For investigation of this research question, data is collected using observation method. The survey instruments were designed to collect data about individual learning activities that may occur inside or outside the classroom, whereas observation data is collected with the purpose of examining the interactions taking place within a classroom.

Observation is a research process which allows researcher to gather live data from a site where some activity is taking place. It is considered to provide more authentic and valid data than provided by other means. Observation is a highly flexible form of data collection and it gives a researcher the flexibility to decide the setting and format of observation Through observation methods, data can be collected about physical environment, resources and the organization of these resources as well as about individuals, their characteristics and their interactions with each other and with the environment (Cohen, Manion, and Morrison, 2011, pg. 456).

The observation can be done using one of the three formats, *highly structured, semi-structured* and *unstructured observations.* In highly structured observation format, observation categories are pre-determined whereas in semi-structured observations, the aim of the observation is pre-determined but expected outcome is not pre-determined. In case of unstructured observation, there is no predetermined agenda about what to observe and expected outcome of observation is also not pre-set. The choice of one of the three formats of observations, unstructured, semi-structured or highly structured completely depends on the aim of the research.

Apart from the setting and format of the observation, the researcher need to decide the degree of participation in the observation process. Researcher's role in the observation is defined on the basis of degree of participation in the activity (Gold, 1958 as quoted in Cohen, Manion, and Morrison, 2011, pg. 456). Researcher can assume one of the four roles: *researcher as* *participant, participant as observer, observer as participant and observer.* Each of these roles are described next.

When the researcher participates fully in the ongoing activity just as other participants she assumes the role of *researcher as participant.* In this role, the researcher gathers data about the activity while participating in the activity. Other participants may not be aware of the researcher's role as an observer while interacting with him or her and may provide natural responses.

In another role of *participant as observer*, the researcher interacts with other participants and participates in the activity but not completely as in the role of researcher as participant. Participants interact with the researcher and they are aware of the researcher's role as an observer. Their responses may not be as natural as in the first form of observation, but by interacting with the participants, the observer can create informal context.

In the third role *observer as participant*, the researcher is a neutral observer. The researcher may interact with the participants but does not take part in the main activity.

The fourth role indicates researcher's complete detachment from the observed activity. In this role of *observer*, the researcher neither participates nor interacts with them. Participants may not even be aware of the researcher's presence and the aim of observation. The most unbiased and naturalistic data is collected by assuming this role.

The role of the researcher in pilot observation was participant-as-observer and for actual observation it was observer-as-participant. In the pilot class observation, the researcher participated in the class activity for a short period while in the later observations, researcher interacted with students informally without participating in the class activity.

Observation research method gives flexibility to researcher to choose the site and decide what to observe. Planning such observations ahead makes the coding and analysis of qualitative data easy, objective and unambiguous (Cohen, Manion, and Morrison, 2011, pg. 459). Therefore, a study design framework was developed before gathering data.

Table 3.4: Study design: Conceptual framework for observation method

Stage number	Stage description	Actions taken
1	Planning of pilot observation	- Prepare a checklist indicating the characteristics and interactions to be observed. - Select a class for pilot observation.
2	Conduct pilot class observation	- Run pilot class observation - Determine categories to be observed in actual class observation. - Develop a coding sheet for actual class observation.
3	Actual class observation	- Select classes with different characteristics, such as course number and gender of students. - Collect and record observation data using field notes and the coding sheet.
4	Analyse data	- Analyse data for each class separately and for all classes together

The Table 3.4 illustrates the stages in the study design adapted for collecting observation data. The first two research stages pertaining to research methodology are explained in the next subsections. The last two stages related to data analysis are described in the chapter 4.

3.13.1 Planning class observation

During the planning stage of observational studies, in order to collect relevant and rich data, researcher must plan ahead the following aspects, which are *focus, sample, method and unit of analysis* and *format of observation* (Cohen, Mainion and Morrison, 2011, pg 459).

The first aspect is to decide the focus of observation and decide boundaries, so that the relevant data needed to investigate the research question can be collected. The aim of the research question 4 is to explore the dynamism in a technology enabled mathematics classroom. The focus of analysis is to explore how learning activities are enriched with the help of digital and non-digital tools in a mathematics class. Accordingly, the focus of observation is on collecting data about the manner in which tools are used by the teacher and students and the impact of students' interaction with different tools on their learning.

The second aspect of observation is to decide the sample. Purposive sampling method is used for selecting information rich cases in qualitative research (Cohen, Manion and Morrison, 2011, pg. 456; Palinkas et al, 2015) After collecting data from teachers' survey, teachers who volunteered to participate in class observation, were contacted. Those teachers were asked to provide details about the tools that they would use in their classes. For attaining maximum variation within the sample, classes were selected to represent all course levels, such as M010, M020 and M030 as well as both genders.

A sample consisting of four classes of four teachers was selected and one of the four classes was selected for pilot observation. All teachers were planning to use different tools except one teacher who was planning to follow a traditional teaching method without using any digital tool to teach. Two teachers were planning to follow collaborative learning and other two teachers were planning to follow traditional learning environment for individual learning. Duration of each class is 50 minutes. Two of the classes were observed in the morning from 10 to 10:50 and two classes were observed between 1:00 and 2:50 pm. Thus it is ensured that the sample provides cases with all possible variations in the learning environment. The data gathered from these samples will yield rich data for investigation of the research question 4.

The third aspect of planning is to decide the unit of observation. Each class and activities observed within that class form a *unit of analysis* for investigation of the research question. One unit of analysis includes characteristics of teacher and students, types of tools and other resources as well as interactions among teacher, students and various tools.

The fourth aspect of planning is to decide the formats for observation as well as for recording and analyzing the data. Though the unstructured or format of observation avoids selectivity, it is recommended for research questions which aim to generate hypothesis (Cohen, Manion and Morrison, 2011, pg. 458). Unstructured observations need little or no planning but data analysis can be time-consuming, whereas, in the semi-structured observation the planning stage is time consuming but data analysis is easy and rapid (Cohen, Manion and Morrison, 2011, pg. 458). In this study, the aim of the research question 4 is not about generating variables or hypothesis, but it is to determine under which conditions the use of tools facilitates learning. Considering the aim of the research, class observations are done using semi-structured format, in which the types of interactions are known a priori but their intensity, frequency and their impact is not known. Though there can be different styles of integrating tools in mathematics classroom, in this context of the study, these styles are countable. Also, according to the Activity theory framework, a number of interactions are anticipated between student and teacher, student and tool, student and peers. These categories of interactions within a mathematics classroom can be determined from a pilot class observation data. Under the chosen theoretical framework, *what is to be observed* is known but the outcome is not known. Thus semi-structured format is feasible and suitable for the current research aim.

In addition to the above four aspects, it is a good practice to anticipate possible barriers in getting necessary data. In order to understand the observed activity, additional information was obtained from teachers prior to the observation. This information was about the topics to be covered, the type of class activity (either group or individual) and the names of tools the teacher intended to use.

The objective of the pilot class observation was to confirm occurrences of expected main categories of interactions as well as look for any un-anticipated interactions. The data from class observations is recorded in the form of transcripts for which structured format is adopted. Frequency of occurrences of different interactions were recorded using codes determined from pilot class observation. Method of coding the observation data offers a framework for organizing useful information. Due to this organized form of observation, the researcher can focus on the specific information needed for the research (Kawulich, 2005).

The checklist shown in the Table 3.5 illustrates the details of class observation plan for pilot observation.

Table 3.5: Checklist for class observation

Criteria	Description- What to observe?	
	Teacher	Student
Focus of observation	What tools are used in class by teacher? What is the purpose of using those tools?	How are students utilizing tools? Are they able to construct their knowledge?
Key features to be observed	Is the learning environment- student centered or teacher centered	How is the learning environment facilitating development of conceptual understanding? What are their additional support seeking patterns?
Possible difficulties	Teacher may face hardware or network failure while teaching	Students may be conscious of observer's presence.

3.13.2 Pilot class observation

The aim of the pilot class observation was to confirm predetermined categories and to generate key points for next observation sessions as well as to examine the trustworthiness of the observation instrument. After completing the planning, the next stage in the study design is to conduct a pilot class observation. Upon confirmation of the categories of interactions, each type of interaction was assigned a code. These categories are then used for recording actual class observation.

In line with the above aim, focus of observation was guided by the following questions.

Is the teacher incorporating any digital tool other than the main tool ALEKS? If yes, how are the tools integrated in teaching? How does the use of tool improve students' learning experience? What type of interactions occur within the classroom? How are students interacting with their peers, teacher and tools? Is this interaction leading to construction of knowledge? Is this interaction leading to greater engagement in learning?

As observed in any regular classroom learning environment, interactions were observed between teacher and the whole class, student and teacher as well as between student and other students. The symbols T, S, Ss and M are used to denote main participants, teacher, student, a group of students and the milieu respectively. These three interactions are coded as T-Ss, S-T and S-S respectively. Code S-S indicates one-to-one interaction whereas S-Ss indicates one student explaining to a group of students. The later type of interaction is specific to a class in which students worked in collaboration. Student's interaction with the main teaching tool used by the teacher is represented by the code $S - Tl$ and their interaction with other tools, such as calculator or dictionary is indicated by S-M.

The class chosen for the pilot observation was a class of M020 and the teacher had planned to teach a lesson from Geometry. Before the class, the teacher had given out the details to the observer about the topic, learning activity and expected learning outcomes as well as the tools being used in class. The expected learning outcomes for this class were set as follows: The students are expected to understand the meaning of the terms *perimeter, area, circumference, diameter, radius* and the symbol π and then apply their understanding to solve related problems. The teacher had more than 15 years of teaching mathematics, out of which, she had used technology to teach for five years. She used the web-based tool named *Screenr* for creating a video. She was also planning to use a spreadsheet software to record measurement data resulting from the class activity.

The duration of this class was from 1:00 to 1:50 pm. The students in this class were all girls in the age group of 17 to 20. They had moderate proficiency in English. The teacher reported that understanding the mathematics vocabulary was challenging for many of them. Also their academic standing was either moderate or low. Some of the students were repeating this course due to failing in the previous cycle.

This class was conducted in a small classroom. Since the teacher was going to adopt collaborative teaching, she had arranged students' desks in clusters. The teacher formed student groups and the students sat in clusters as per the teacher's instruction. The students were encouraged to collaborate with other members in the group.

The classroom had a teacher's computer which was connected to the Internet and a digital whiteboard. The digital whiteboard also works as the screen for displaying presentation slides and videos. All students had their iPads connected to the Internet. During the class, there were no issues reported related to the network or other hardware failure.

The teacher had developed short videos for explaining the key concepts. She had embedded hands-on activity in which students were asked to measure circumference of ring-shaped objects. Each group of students was provided with three different sized circular objects and a measuring tape. They were also given paper worksheets to solve. She explained this activity by showing photographs which is an effective way of explaining by overcoming the English language barrier.

Apart from using the main tool ALEKS, the teacher used the spreadsheet software as a supporting digital tool and other physical tools, such as measuring tape and circular objects. The milieu for this class activity consisted of these physical tools, scientific calculators, formula sheets, worksheets to take notes and students' iPads.

The teacher introduced the observer to the students before the class began. The students were told about the purpose of the class observation and they were comfortable with the observer. The observer sat with students in one corner from where it was possible to observe teacher's presentation as well as students' activities and their interactions.

In the first five minutes of the class, teacher marked students' attendance and immediately sought their attention by showing the presentation slides on the big screen. The teacher explained to the students the expected learning outcomes of the whole unit as well as the specific topic with the help of a PowerPoint presentation displayed on the projector screen. The teacher showed a presentation made by her in which a video clip and animated graphics were embedded for explanation. Students watched the presentation for 7 minutes and then started to work on their activity.

The activity was to measure circumference and diameter of three circular objects. They had to enter their measurements on a common spreadsheet on teacher's desktop. During the next 15 minutes, students were doing the measurement activity, while teacher went around the tables. Some students sought help from the observer. The students were slow in the beginning due to fear of making a mistake but as the lesson developed students clearly wanted to be involved.

During this period, interactions were observed between *teacher and student*, *student with other students* and between *student and the milieu*. These three interactions are coded as T-Ss, S-

Ss and S-M. The event of teacher explaining to the whole class is denoted by the code T-Ss while the event of teacher explaining to individual student is denoted by the code T-S.

As they finished their measurement activity, the teacher asked one student from each group to enter their measurement data on a common spreadsheet on her computer. The students did not hesitate to complete this activity. All students were able to share their measurements with the whole class through the common spreadsheet. The teacher could collect a sizeable data for plotting graph of two measurements, circumference and diameter for 12 different objects. This demonstrated that teacher involved them into constructing the lesson. The students showed a positive attitude towards learning by participating in this group activity. During this period, interactions were observed between the teacher and the tool and student and the tool. Events of the type *teacher-whole class* or *teacher-student* were not observed during this time, which indicates that learning environment was changing from teacher-centered to student-centered. The students were becoming more active in learning and they needed little support from the teacher.

The teacher used the spreadsheet tool to generate a scatter plot using the data entered by the students. This was a good utilization of the spreadsheet tool which demonstrated a link between tabular and graphical representation of the same dataset. The students watched these dynamic multiple presentations on the big screen which helped them visualize the equivalence between tabular and graphical representation of data. This dual representation was instant and students were engaged in watching it. The straight line graph based on the measurements of circumference and diameter indicated that the ratio of these two quantities is always constant and is approximately equal to 3.14. The meaning of the symbol π was unfolded from the constant ratio.

One of the measurement was deviated from other observations. The teacher asked the students to explain its deviation from other values. Immediately, the group of students, who reported that value answered that this could be a mistake. They checked their measurement and realized that there was a measurement error, which they fixed immediately. The teacher encouraged them to reflect on their activity and it provided an opportunity for deep learning.

For explaining the concept of perimeter of a rectangle, the teacher showed an animated presentation, in which a shiny star was moving along the borders of a rectangle. This and other similar aminations were effective for understanding the terms perimeter, circumference, diameter and radius. With the help of the measurement activity, the concept of circumference and diameter were emphasized. Demonstration of scatter plot emphasized the concept and meaning of the symbol π. Overall, the tools used by the teacher were effective in increasing students' engagement in learning. Their learning was facilitated due to their interactions with the community and with the tools as proposed by the Activity theory framework. They were encouraged to interact with peers and were allowed to use other resources as the teacher had adopted collaborative setting and the rules of collaboration were set clearly in the beginning.

Now the teacher wanted to check if they could solve problems related to area, perimeter and circumference. The teacher set the next activity of solving problems taken from the ALKES repository. She also guided them about where to find more similar problems on ALEKS so that they can master them at home.

The students had a better conceptual understanding to solve the problems as they have learned the meaning of fundamental terms. But still this part was not equally easy for all students. Many students still struggled to remember and map their understanding of vocabulary to the problem context, which was evident from their interactions with each other. They confirmed their understanding with each other and where necessary looked for the Arabic meaning of the words on Google translate on their iPads.

The students used the spreadsheet tool as per teacher's instruction. There was no more engagement and efforts to understand the tool. They used this tool as a *master*. This could be due to the fact that the tool was not available to them on their iPads and they were asked to do a very small activity with that. But they used their iPad for surfing as well for calculation as a servant. This observation suggests that overall proficiency of using a tool to achieve the learning outcome may improve if personalized tools are used which demand active participation.

The activity of collecting measurements and then deriving the value of π could have been completed without the iPad and other digital tools, however, collaboration and use of the graphing tool kept the students more engaged and focused. It helped them in developing the understanding of the concept of π. It can be said that the teacher used the spreadsheet tool to *Extend* her teaching. Due to the limited use of the spreadsheet tool and use of physical artefacts, such as circular objects, this learning experience is limited to the classroom environment. It is not possible for students to replicate this activity without teacher's guidance.

The teacher did not measure the learning outcome through a formative quiz, but she gave feedback to students about their work. It was observed that 80% of students were successful in solving the problems in class. But 100% of students showed interest and engagement in learning. It can be argued that the use of tools definitely increases student engagement and interaction with peers and other resources facilitates learning.

Based on the pilot observation data, a coding sheet was designed for subsequent structured observations (Cohen, Manion, and Morrison, 2011, pg 459-460). The observation notes and the structure of the coding sheet was discussed with the same teacher to ensure the congruence between the recorded details of the observation and the actual event. The teacher confirmed the accuracy of the event details which in turn confirmed the trustworthiness of the observation format.

Coding sheet for class observation is shown in Table A1-5 in Appendix-1.

3.14 Ethical considerations

The research proposal was reviewed by the research ethics committee of the institute It was evaluated by the institute's Applied Research Ethical Panel in accordance with the Standards for Protection of Human Subjects and the respective policies and guidelines. The Research Ethical panel found that the research protocol posed no more than minimal risk. The research project had therefore given ethical clearance and the researcher was given approval for data collection from the students and teachers in the institute based on the protocol described. This approval also entitled the researcher to collect data from ALEKS logs. Refer to the letter presented in the Appendix -4.

This study involves University students who are adults, therefore their consent about participation in the research was sufficient. The items in the survey instrument neither solicited answers to any sensitive issues, nor it attempted to cause any physical or psychological damage to participants. A written explanation was provided to them in English and Arabic about the purpose and scope of the research. Both the questionnaires clearly mentioned that the participation in the surveys was voluntary. The students were assured that their opinions will be kept confidential and they were requested to give a written consent about voluntary participation. They were aware about the fact that teachers can monitor their learning activities on ALEKS in order to provide them timely support. They were requested to provide their student number, but they were informed about the fact that this information was used only for the research purpose and their coursework grades were not affected due to their responses to survey items.

During a personal meeting with participants prior to the class observation, it was explained to them that they will be participating in a group and their identity and opinions will not be revealed to anyone. Also, they were assured that they have the right to withdraw at any stage. During the same conversation a quick question was asked to check if they understood their role and their rights.

During class observations, students were identified with codes and not by their names or student numbers. No videos or photographs were taken according to the cultural practices. The data collected from class observations was recorded as written transcripts only.

In the teacher's questionnaire, participants were asked if they could be contacted for observing their classes. In the report of findings, information about their names and locations is not revealed. Also, the draft report was discussed with the participants and their approval was taken before finalizing the report. All data are stored in a digital form in at least three different secure locations to avoid loss or damages. Furthermore, the standards to protect the anonymity, confidentiality, and rights of the participants was reviewed by the Ethical Review Board (ERB) at BUID. Refer to the details given in the Appendix-3.

3.15 Summary

In this chapter, an overview of the study design adopted for both quantitative and qualitative part is presented. The complete process of developing and validating the survey instruments was presented.

After performing factor analysis, it was found that all items from student's survey loaded into exactly one factor with a high factor loading and the instrument exhibited high reliability. 29 items from part-1 were reduced to five factors and 15 items from part-2 were reduced to five variables representing students' study habits. Similarly, all items in the teacher's survey were loaded into exactly one factor and exhibited high consistency.

List of items in part-1 and part-2, their sources and results of reliability and confirmatory factor analysis for each are given in the Tables A1-1 and A1-2 respectively in the Appendix-1.
For the qualitative part of this research, format for class observation is developed.

4. Data analysis

In this chapter, results of analysis of data collected from both surveys as well as class observations are presented. The chapter begins with the analysis of students' data which is then followed by analysis of teachers' survey data and then analysis of observation data. An overview of methods applied for data analysis is presented next.

Associations between various factors are examined using correlation analysis and investigation of potential causal chain linking different variables is done by applying methods of *path analysis*. Path analysis is a statistical method which allows researcher to set a multivariate model and improve its fit statistically. Path analysis is one of the techniques grouped under the methodological toolkit of Structural Equation *Modelling* (SEM). It is a statistical technique based on multiple regressions but it is more robust to the deviation of variables from normality (Cohen, Manion, and Morrison, 2011, pg 692-693). Using the conceptual model presented in chapter 3 (Figure 3.2) as a basis, a multivariate operational model is proposed. It is a model showing causal chain of relationships among different variables including direct and indirect association.

Cluster analysis enables the researcher identify homogenous groups from data and reveals the characteristics of these groups (Cohen, Manion, and Morrison, 2011, pg 685). Groups of students with similar study habits are determined by applying methods of cluster analysis. Similarities and differences in the perceptions and study habits of these student groups are determined by applying independent samples tests.

The two demographic variables *gender* and *module number* separates students into two and three groups respectively. Non-parametric tests are applied to examine the similarity and differences among these groups, as mentioned in the section 3.9.

The qualitative data is analysed by applying *analytic induction process* (Cohen, Manion, and Morrison, 2011, pg 557). Following the framework of analytic induction process, observation data is scanned to generate categories and then plausible relationship between the categories is investigated. Occurrences of these categories in each unit observation are counted. Extracting quantitative information from the qualitative data is recommended as it allows the researcher to support the findings with amount of evidence (Maxwell, 2008, pg 246). Then data gathered from three actual class observations are compared with each other to find similarity and differences in teaching practices and their impact on learning.

The details of each of these data analyses are presented in the following sections.

4.1 Descriptive statistics

Descriptive statistics discovers trends in the data and describes the important characteristics of the data. As mentioned in the section 3.9, for each factor, the mean score of all components was calculated. These scores are on a continuous scale and the descriptive statistics for each of these variables were calculated. In order to examine the frequency distributions of these scores, they were transformed into ordinal scale from 1 to 5. Similar to the original scale, the score 1 indicates strong agreement and 5 indicates strong disagreement.

Table 4.1 shows percent frequencies and mean, median for all factors from part-1.

Table 4.1: Percent frequencies and descriptive statistics- Part 1

Scale value	Tutoring effect of ALEKS	Ease of use of ALEKS and its effect on interest in mathematics	Cognitive effect of ALEKS	Perceptions about use of tools in learning mathematics	Belief about learning with any digital tool

Percent frequencies					
Strongly agree	18.4	21.9	16.4	3.0	4.0
Agree	54.2	50.2	59.7	13.9	26.9
Neutral	20.9	20.4	18.9	41.3	52.2
Disagree	4.0	5.0	2.5	34.8	14.4
Strongly	2.5	2.5	2.5	7.0	2.5
Descriptive statistics					
Mean	2.18	2.16	2.15	3.29	2.85
Median	2.00	2.00	2.00	3.00	3.00
Mode	2	2	2	3	3

It can be seen from the Table 4.1, that a high percent of students (72.6%) agreed that they find ALEKS effective in studying mathematics 72.1% expressed that ALEKS is easy to use and due to its use their interest in mathematics has increased. 76.1% perceive that ALEKS helped them understand mathematics. 52.2% of students are neutral about what is the correct way of learning mathematics using tools. They neither agree or disagree to perceptions about whether every problem can be solved using some kind of tool, whereas 31% think that once they have some kind of digital tool, they can depend on it for problem solving.

Values lower than 3 for factors in part-1 indicate positive perceptions or belief and higher scores indicate the contrary. It can be seen from the descriptive statistics, that students are neutral about effectiveness of computer tutor in studying mathematics in general. (Mean=3.29), but they agree that ALEKS is an effective computer tutor (Mean=2.18). Also overall there is an agreement that ALEKS is easy to use and it has a positive impact on their mathematics understanding. (Mean=2.16 and 2.15 for Factor 2 and Factor 3 respectively).

A majority of students (approximately 77%) confided that they follow systematic study habits very often. Approximately 58% agreed that they use ALEKS systematically by reading the explanation, selecting topics in correct order. 36% expressed that they take external help either very rarely or never, which could possibly indicate that ALKES provides them enough support for learning independently. Refer to the Table 4.2.

Table 4.2: Percent frequencies and descriptive statistics- Part 2

Scale value	Systematic study habit	Systematic tool use	Help seeking	Coping with failure	Distracted by other activities
Percent frequencies					
Always	29.4	11.9	9.5	6.0	21.5
Very often	47.8	45.8	19.4	15.4	27.0
Sometimes	19.9	32.8	36.3	36.3	27.0
Very rarely	3.0	8.5	32.3	30.3	14.5
Never	0.0	1.0	2.5	11.9	10.0
Descriptive statistics					
Mean	1.97	2.41	2.99	3.27	2.65
Median	2.00	2.00	3.00	3.00	3.00
Mode	2	2	3	3.00	2.00[a]

Referring to the scale of "Always (1), Very often (2), Sometimes (3), Very rarely (4) and Never (5)" as defined in the survey instrument, if an item in part (2) has a score less than 3 then it indicates that study habits represented by that item are adapted often. It can be seen from the Table 4.2, that the mean scores for systematic study habits and systematic tool use is equal to 2. It indicates that almost all students reported that they often take a systematic approach in studying mathematics as well as while using ALEKS. Most of them have reported that sometimes they do waste time on unnecessary tasks and they give up when they fail. (mean = 2.65 and 3.27 for study habit 4 and 5 respectively). Also they do not take external help often. (Study habit 2, mean=2.99).

The descriptive statistics from survey data reveals an overall positive perception about effectiveness of ALEKS, but further exploration was done by performing cross-tabulation analysis on gender and each of these perceptions. A summary of this gender wise percent frequencies is given in the following Table 4.3.

Table 4.3: Gender wise percent frequencies of perceptions

	Tutoring effect of ALEKS				
	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Female	22.1%	58.8%	16.9%	2.2%	0.0%
Male	10.8%	44.6%	29.2%	7.7%	7.7%
	Ease of use of ALEKS and its effect on interest in mathematics				
	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Female	27.2%	51.5%	18.4%	2.9%	0.0%
Male	10.8%	47.7%	24.6%	9.2%	7.7%

	Perceptions about use of tools in learning mathematics				
	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Female	2.2%	14.0%	39.0%	39.0%	5.9%
Male	4.6%	13.8%	46.2%	26.2%	9.2%
	Cognitive effect of ALEKS				
	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Female	20.6%	60.3%	17.6%	1.5%	0.0%
Male	7.7%	58.5%	21.5%	4.6%	7.7%
	Belief about learning with any digital tool				
	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Female	4.4%	27.2%	52.2%	16.2%	0.0%
Male	3.1%	26.2%	52.3%	10.8%	7.7%

It can be seen from the Table 4.3, none of the female students strongly disagreed about the four factors except the factor measuring their perceptions about learning with tools. 5.9% female students reported that in general, computer tools may not be very useful. Probably, their previous experience about learning with tools was not positive.

The male students are more conservative in expressing their perceptions about effectiveness of ALEKS. They prefer to agree but not strongly agree, contrary to strong feeling of female students. The percentage of male students (17%) who do not perceive ALEKS as easy to use tool is higher than the percent of female students (3%) with similar opinions. A majority of both male and female students (approximately 52% each) has neutral perceptions about beliefs about learning with tools. It points to the fact that they have mixed beliefs about learning with tools. Whether the perceptions of male and female students differ significantly is examined in the later section of predictive analysis.

Before investigating causal relationships among these perceptions and study habits, an overview of variables extracted from ALEKS data logs is presented in the next subsection.

4.2. Variables from ALEKS data logs

The data logs of ALEKS include details of total time spent, number of topics attempted, number of topics mastered and average number of topics mastered by each student. It is important to examine which of these variables are potential predictors of final marks in the course.

A student may log in to the system but not attempt to master a topic. This *idle time* is included in the total time spent on ALEKS and may not provide accurate information about the time spent on learning. In a preliminary analysis, a weak positive and non-significant correlation was found between the variable representing average time per week and the overall marks in the course (Final average) ($r = 0.102, p = 0.06, \alpha = 0.05$).

Also, since students are encouraged to learn at their own pace, time taken to master a topic or average number of topics mastered per hour cannot be considered as an important indicator of learning. In general, the system generated attributes, such as *time_spent* and *average number of topics mastered per hour*, may not provide accurate information about student's learning efforts therefore a derived attribute is defined by taking the ratio of the two variables *number of topics mastered* and *number of topics practiced* to investigate students' learning patterns (Dani, 2015; Dani and Nasser, 2016). This ratio is represented by the variable *mtop*[2]. A high value of this variable indicates that a student is able to master most of the topics she is attempting to master, whereas a low value indicates that a student is practicing many topics but not able to master many of them. Its value indicates a level of efforts exhibited by the students as well as her ability to master the course content independently. The overall mean value for the variable *mtop* is found to be equal to 0.70, which means on average students are able to master 70% of the topics they attempt to master. Average time spent is 44 hours during the cycle of 8 weeks. Detail analysis of student learning activities using these variables is presented in the section 4.4.

4.3 Operational model for research question 1 and 2

In order to examine students' study habits and their different ways of interacting with the tool and the possible effect of these two habits on the achievement of their learning goals, an operational model is developed from the conceptual model. This model is developed using the latent variables introduced in the students' survey instrument. The conceptual model is transformed into an operational model by mapping each latent variable into the corresponding factor extracted as discussed in chapter 3. In this section, a discussion about the development of the operational model is presented.

As discussed in chapter 2, the theory of instrumentation implies that as the student masters the skills of using the tool, his or her understanding of mathematics develops and vice versa. While operationalizing this principle, the associations between the pairs of factors, such as *Systematic uses of tools* and *tutoring effect* and *Systematic use of tools and cognitive effect*,

[2] *mtop* indicates ratio of mastered to practiced

impact of study habits on this association needs to be examined. The Activity Theory framework claims that the student’s interaction with the tool (measured by tutoring effect) and with the community (measured by study habits) mediates the process of achieving their learning goal (measured by their marks and perceptions about the cognitive effect of ALEKS). Therefore, the mediational effect of student’s study habits on the association between the tutoring effect and final marks as well as between the tutoring and cognitive effect must be examined. At this stage it should be noted that the affective factors, such as perception about ease of use of ALEKS, use of tools in general and beliefs about learning with computers are not part of the conceptual model, as it is developed on the basis of Activity Theory framework. Therefore, though these variables are measured in this study, they are not included in the operational model. But it is hypothesized that these factors may predict one of the important factors of the operational model, which is the tutoring effect of ALEKS. Verification of this hypothesis is done separately in the section 4.**7**.

As noted before, ALEKS provides individual tutoring, instant feedback on learning and flexibility to learn at one’s own pace. It also provides personalized learning environment for students, facilitating student centered learning. Though this approach is promising it also implies that students are expected to develop self-regulatory abilities. Unlike traditional paper-based mathematics textbooks, ALEKS provide flexibility of choosing topics from any chapter in any order. Some students may attempt to master many topics from the course in a short time, without organizing their learning tasks and may choose topics randomly contrary to systematic use of ALEKS (Dani, 2016). On the other hand, some students organize their learning tasks by keeping study notes, reading questions and explanations carefully and by reviewing their previous work, which indicates their active participation in learning. It is examined if these study habits have any influence on their learning activity in which they use a tool. Thus the model hypothesizes direct and indirect association between several variables which are represented using a path model. The impact of one variable on the association of the other two variables is tested using *Mediation analysis*, which is explained in the next subsection.

Other two study habits measured from the student survey, which are persistence and distraction were excluded from the saturated model as shown below, because these two factors were not found to be correlated with other habits or factors.

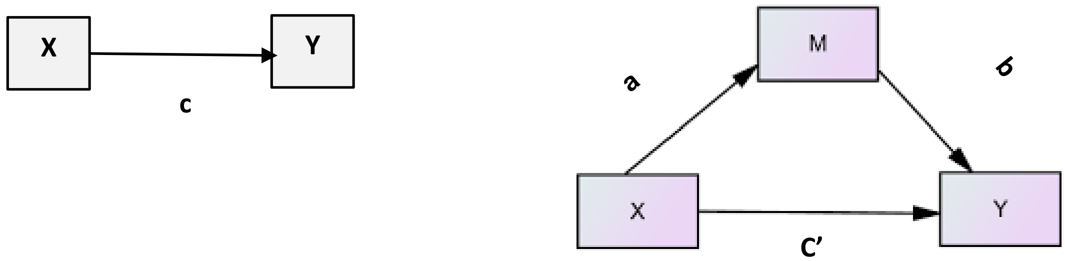
Mediation

An independent variable (denoted by X) can cause a dependent variable (denoted by Y). The notation $X \rightarrow Y$ is used in a path model to indicate that there is a causal relationship between X and Y. The causality can be examined by running the regression analysis. The regression weight is shown on the direct path between X and Y. Third variable M can be caused by X and in turn, it can cause the variable Y. If the regression weight along the direct path between X and Y is less than the total regression weight along the two paths $X \rightarrow M$ and $M \rightarrow Y$, then the variable M has a mediating impact on the association between X and Y. (Warner, 2008, Pg. 648-649).

The following Figure 4.1 illustrates that there is a direct path between independent variable X and dependent variable Y and indirect path through the variable M.

Figure 4.1: Conceptual representation of mediating effect

Total effect **Direct and indirect effect**



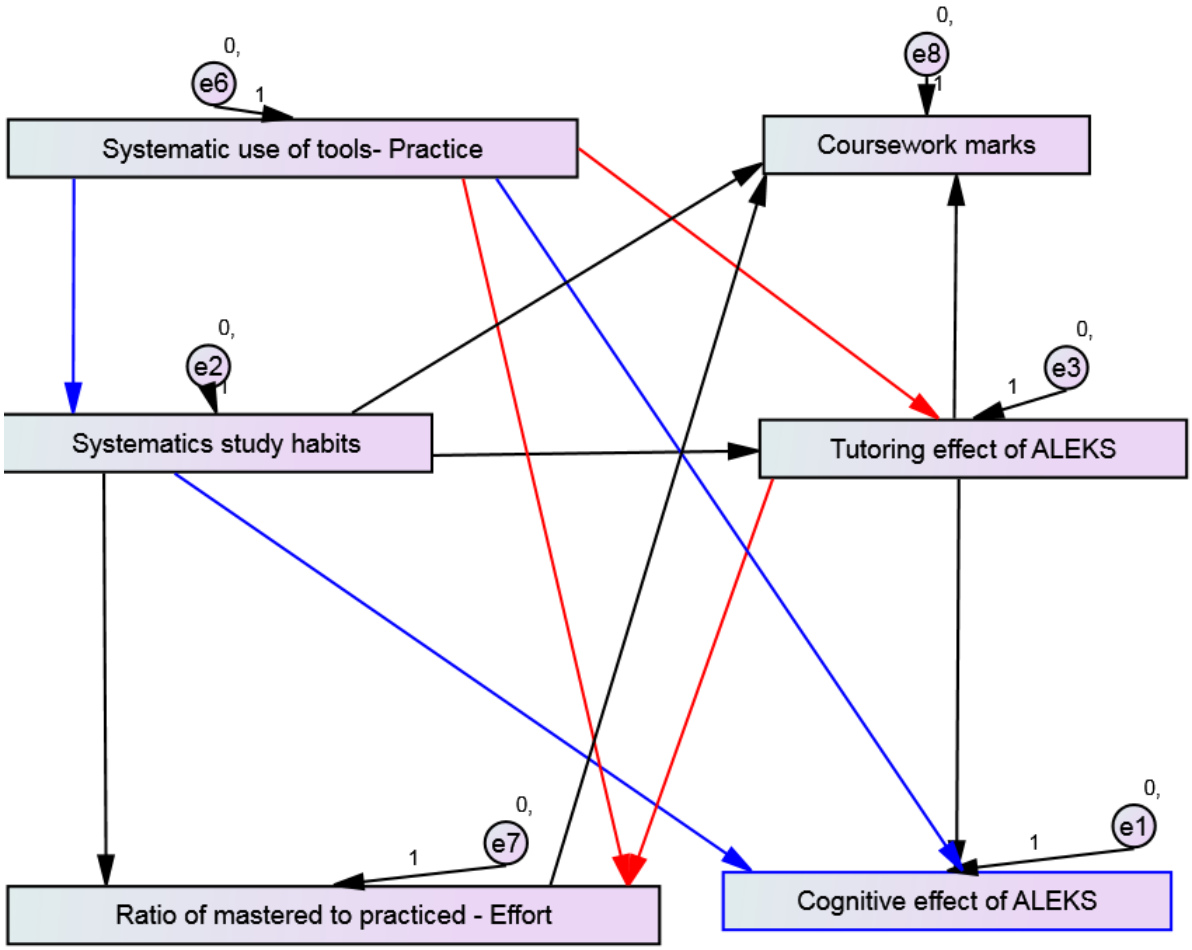
The regression weight c indicates the total effect of X on Y, the product of weights a and b indicates the indirect effect and c' indicates the direct effect of X on Y.

The total effect is calculated as $c = c' + a \times b$. If c' is significant and not too small, then the variable M has a partial mediating effect on the causal association between X and Y, which means X has some direct effect on Y as well as its effect on Y is influenced by M (Warner, 2008, pg. 649).

The null hypothesis in this case states that the variable M has no mediating effect on the association between the variables X and Y. Statistical evidence for rejection of the null hypothesis favours the claim that the variable M has mediating effect on the association between X and Y.

Based on the theoretical, conceptual model and the constructs used to measure the variables in the conceptual model an operational model is developed. This model is presented in the Figure 4.2.

Figure 4.2: Operational model for research question 2 and 3



The following hypotheses are set up to examine the components of each path shown in this model.

H1. Students' perceptions about the tutoring effect of ALEKS have a positive impact on students' perceptions about the cognitive effect of ALEKS.

H2. Students with positive perceptions about the tutoring effect of ALEKS score higher on the course exams.

H3. Student's Systematic study habits improve the effect of systematic use of tools on the perceived tutoring effect of ALEKS.

H4. Student's Systematic study habits improve the effect of systematic use of tools on the perceived cognitive effect of ALEKS.

H5. A positive tutoring effect of ALEKS improves the effect of systematic study habits on perceived cognitive effect of ALEKS.

H6. The impact of perceptions of the tutoring effect on coursework marks is improved by actual efforts.

The associations among variables as shown in Figure 4.2 is examined by applying the method of Structural Equation Modelling (SEM) (Cohen, Manion, and Morrison, 2011, pg. 692-693). Details of this analysis are given in the following section.

Testing the operational model

As stated in chapter 3, all variables collected from surveys do not follow a normal distribution, therefore application for path analysis using SEM, is more appropriate, because the methods of structural equation modelling are robust to the deviation from normality. The path analysis for the conceptual model shown in Figure 4.2 is done using the software AMOS. The maximum likelihood method was applied and bootstrapping was performed to get estimates of the regression weights along all paths shown in Figure 4.2.

As recommended by Cohen, Manion, and Morrison (2011, pg. 694), it is necessary to examine and report the goodness of fit of the model established above. The Normed Fit index (NFI) and Comparative Fit Index (CFI) should be 0.9 or higher and p-value of the Chi square statistics should be >0.05. The Chi-square statistic value is 2.991 with a p-value 0.886. Both the NFI and CFI values are equal to 1. These scores indicate that the model satisfies the conditions of goodness of fit and hence results produced here are acceptable.

In this section, discussion of hypotheses stated in section 4.3 above is presented. In each of the following subsections, the null hypothesis (denoted by H_0) and alternate hypothesis (denoted by H_A) are stated. These are followed by the results and interpretation of hypothesis testing.

From the list of hypotheses identified above, hypotheses H1 and H2 examine the association between two variables only, whereas H3 to H6 examine the influence of a variable on the association between two other variables. Hypotheses H3, H4, H5 and H6 are tested using medication analysis. The hypotheses are tested by using the statistics about regression weights, direct and total effects obtained from the AMOS output, as discussed below.

Impact of tutoring effect of ALEKS on cognitive effect

$H1_0$: There is no impact of perceptions about the tutoring effect of ALEKS on perceived cognitive effect of ALEKS

$H1_A$: Student's perceptions about the cognitive effect increases as the score for the tutoring effect increases.

A strong, positive and significant correlation is found between tutoring effect and cognitive effect ($r = 0.705, p = 0.0$). There is a statistical evidence to reject the null hypothesis It is justified to state that when students' have positive perceptions about tutoring effect they are more likely to feel that ALEKS develops their mathematics understanding. This is a bi-directional association, implying that as students' conceptual understanding increases, they are more proficient in using ALEKS to their advantage. Consequently, they feel that ALEKS is a more effective tutor and helps them in learning mathematics. This conforms to the principle of instrumentation theory.

Impact of tutoring effect of ALEKS on students' coursework marks

Note here a value lower than 3 for the tutoring effect implies that students agree that ALEKS provides good tutoring support in their learning and a higher score indicates disagreement. Therefore, it is hypothesized that if the score for the variable *factor1* decreases, the student is more likely to score higher in the coursework.

$H2_0$: There is no impact of perceptions about tutoring effect of ALEKS on coursework marks.

$H2_A$: Student's coursework marks increase as her score for tutoring effect decreases.

A weak, negative, but significant correlation is found between tutoring effect and coursework marks ($r = -0.19, p = 0.0$). There is a statistical evidence to reject the null hypothesis. It is justified to state that when students' have positive perceptions about tutoring effect they are more likely to score high in the course exams. The weak correlation implies that there may be other factors causing variation in the coursework marks. Further investigation may be needed for this.

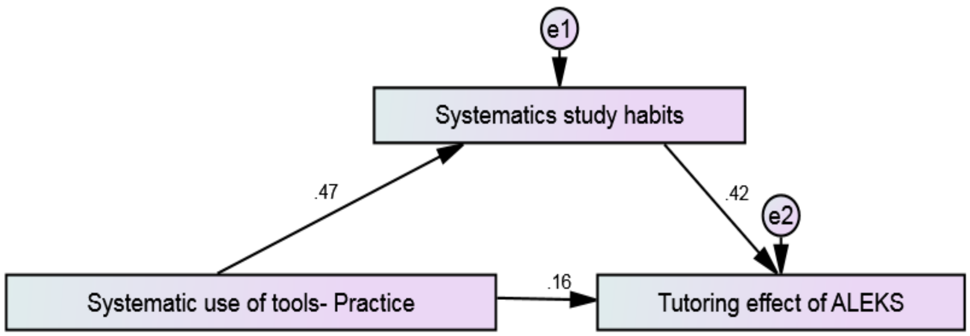
Impact of study habits on the association between tool use and tutoring effect

The students can organize their learning activities while using ALEKS. For example, they do not choose the topics to master in a random sequence, they read the explanation and feedback carefully and review previously mastered topics regularly. These habits indicate habits of using ALEKS systematically.

A student's systematic study habits, such as taking study notes during the class discussion and solving problems step by step while using ALEKS, indicate active participation in learning and taking responsibility of own learning. This active engagement in learning may facilitate cognitive development.

It is hypothesized that adopting these systematic study habits more often while using ALEKS, will increase the impact of ALEKS on the development of mathematical knowledge. In this case, it should be examined if the variable *systematic study habits* (SHabit1) have any mediating effect on the association between the variables *systematic use of tools (SHabit3*) and the perceived *tutoring effect of ALEKS (Factor 1)*. Refer to the path model in Figure 4.3.

Figure 4.3: Path model for hypothesis 3



Null and alternate hypotheses are set as follows:

$H3_0$: Systematic study habits do not change the effect of systematic use of tools on the perceived tutoring effect of ALEKS. (The variable SHabit3 has no mediating effect on the association between the variables SHabit1 and Factor1.)

$H3_A$: Systematic study habits improve the effect of systematic use of tools on the perceived tutoring effect of ALEKS.

Refer to the following Table which shows the standardized direct and total effects. The mediating effect of a variable is established if the total effect of the variable Shabit3 is greater and significant than its direct effect on the variable Factor1 (Little et al, 2007).

From the Table 4.4, it can be seen that the total effect of SHabit3 on Factor1 ($r = 0.360$, Sig=0.00) is greater and significant than the direct effect of SHabit3 on Factor1 ($r = 0.160$, Sig=0.42). Therefore, there is an evidence to reject the null hypothesis and accept the alternate hypothesis confirming that systematic study habits improve the effect of systematic use of tools on the perceived tutoring effect of ALEKS. (Note: *** in AMOS output indicates a very small value).

Table 4.4: Standardized direct and total Effects-Hypothesis 3

Indicated path	Estimate	P	Standardized Direct effect	Standardized Total effect
Shabit1<---Shabit3	.441	***	0.475	0.475
Factor1<---Shabit1	.404	***	0.421	0.421
Factor1<---Shabit3	.143	.042	0.160	0.360

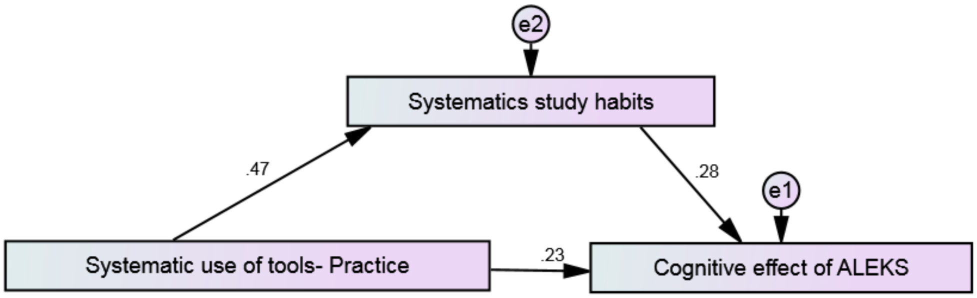
Effect of study habits on association between tool use and cognitive effect

The effectiveness of systematic use of tools of the perceived cognitive effect of ALEKS may be augmented by adopting systematic study habits more frequently. Similar to the discussion above, this can be examined by testing if the variable SHabit3 has any mediating effect on the association between the variable (SHabit1) and cognitive effect. The null and alternate hypotheses are as follows:

$H4_0$: Systematic study habits do not change the effect of systematic use of tools on the cognitive effect. (The variable SHabit3 has no mediating effect on the association between the variables SHabit1 and Factor3.)

$H4_A$: Systematic study habits improve the effect of systematic use of tools on the cognitive effect.

Figure 4.4: Path model for hypothesis 4



From the Table 4.5, it can be seen that the total effect of SHabit3 on Factor 3 (0.359, p=0.006) is greater than the direct effect of SHabit3 on Factor3 (0.225) and the estimates are significant. There is an evidence to reject the null hypothesis. It can be stated that the students who use ALEKS systematically and also adapt systematic study habits, have more positive perceptions about the cognitive effect of ALEKS than those who only use ALEKS systematically.

Table 4.5: Standardized direct and total effects –Hypothesis 4

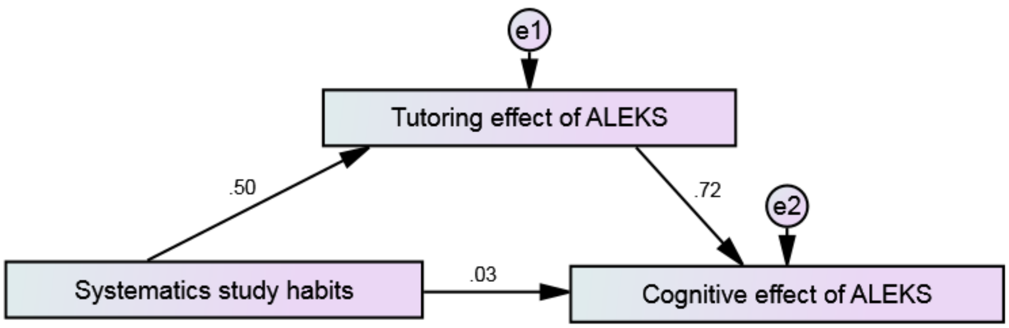
Indicated path	**Estimate**	**P**	**Standardized direct effect**	**Standardized total effect**
Shabit1<---Shabit3	.441	***	0.475	0.475
Factor3<---Shabit1	.241	***	0.283	0.283
Factor3<---Shabit3	.178	.006	0.225	0.359

Impact of tutoring effect on the association between systematic study habits and cognitive effect

$H5_0$: Perceptions about the tutoring effect of ALEKS do not change the impact of systematic study habits on the cognitive effect. (The variable Fator1 has no mediating effect on the association between the variables SHabit1 and Factor3.)

H5A: Positive perceptions about tutoring effect of ALEKS improve the impact of systematic study habits on the cognitive effect.

Figure 4.5: Path model for hypothesis 5



From the Table 4.6, it can be seen that the total effect of SHabit1 on Factor3 (0.389) and the direct effect of SHabit1 on Factor3 is only 0.030).

Table 4.6: Standardized direct and total effects -Hypothesis 5

Indicated path	**Estimate**	**P**	**Standardized Direct effect**	**Standardized Total effect**
Factor1 <---Shabit1	.477	***	0.497	0.497
Factor3<--- Factor1	.642	***	0.724	0.724
Factor3<---Shabit1	.025	.636	0.030	0.389

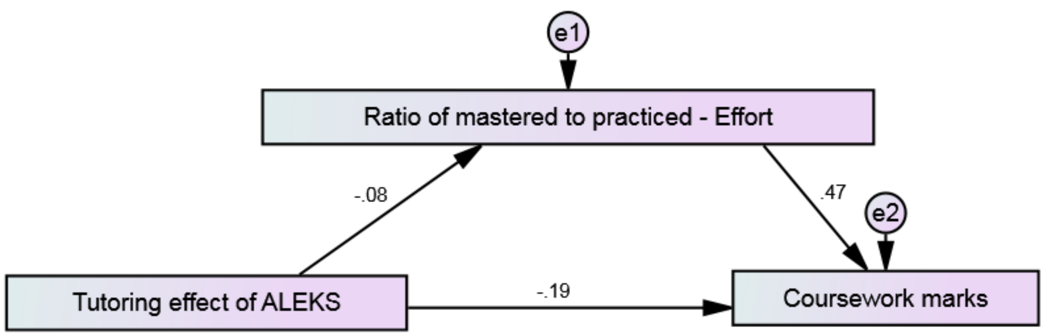
The standardized regression weights along the paths from $Shabit1 \rightarrow Factor1$ and from $Factor1 \rightarrow Factor3$, were found to be significant, but not significant along the direct path between $Shabit1 \rightarrow Factor3$. There is a possibility that the variable *perceptions about tutoring effect* completely mediates the effect of *systematic study habits* on perceptions about mathematical understanding (Warner, 2008, pg. 648). This implies that students who perceive that ALEKS is an effective tutoring tool also feel that their mathematical understanding is developed due to ALEKS irrespective of the frequency of adapting systematic study habits.

Impact of the tutoring effect on coursework marks is improved by actual efforts

H6$_0$: Actual efforts have no impact on the association between the perceptions about tutoring effect on coursework mark.

H6$_A$: As the efforts level increase, the impact of perceptions of the tutoring effect on coursework marks is improved.

Figure 4.6: Path model for hypothesis 6



Standardized regression weights were found to be significant along the paths from $mtop \rightarrow AleksScore$ and from $Factor1 \rightarrow AleksScore$, but not significant along the direct path between $Factor1 \rightarrow mtop$. Refer to the Table 4.7.

Table 4.7: Standardized total and direct effects- Hypothesis 6

Indicated path			**Estimate**	**P**	**Standardized Direct effect**	**Standardized Total effect**
Mtop	<---	Factor1	-.083	.302	-0.083	-0.083
AleksScore	<---	mtop	78.958	***	0.472	0.472

AleksScore	<---	Factor1	-5.278	.006	-0.192	-0.231

From the above statistics, the null hypothesis can be rejected. This statistical conclusion points to the fact that student's increased ability to learn independently improves the impact of tutoring effect on coursework marks. It also indicates that the variations in levels of student's actual efforts are not caused due to variations in the perceptions about tutoring effect, but actual mastery on all topics depends both on the perceptions as well as efforts. The students who only perceive ALEKS as an effective tutor may not score as high as compared to students who have positive perceptions about the effectiveness of ALEKS also make efforts to master most of the topics that they attempt.

This section examined the path model involving survey variables. Analysis of association among variables extracted from the ALEKS data logs is presented in the next section.

4.4 Analysis of ALEKS data logs

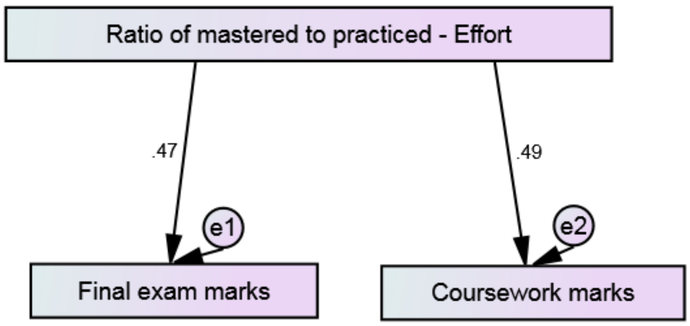
According to the proposed conceptual model, it is hypothesized that higher level of efforts will lead to higher levels of academic achievement, which is formulated and tested as stated below.

$H7_0$: Student's final marks do not depend on the value of *mtop*.

$H7_A$: A high value of *mtop* indicates high overall marks in the course.

After applying the SEM regression test, it was found that there is a moderately strong, positive and significant standardized regression coefficient along the path from the variable *mtop* to student's final exam marks as well as the coursework mark ($r = 0.5, p = 0.0, \alpha = 0.05$). Refer to the following path diagram.

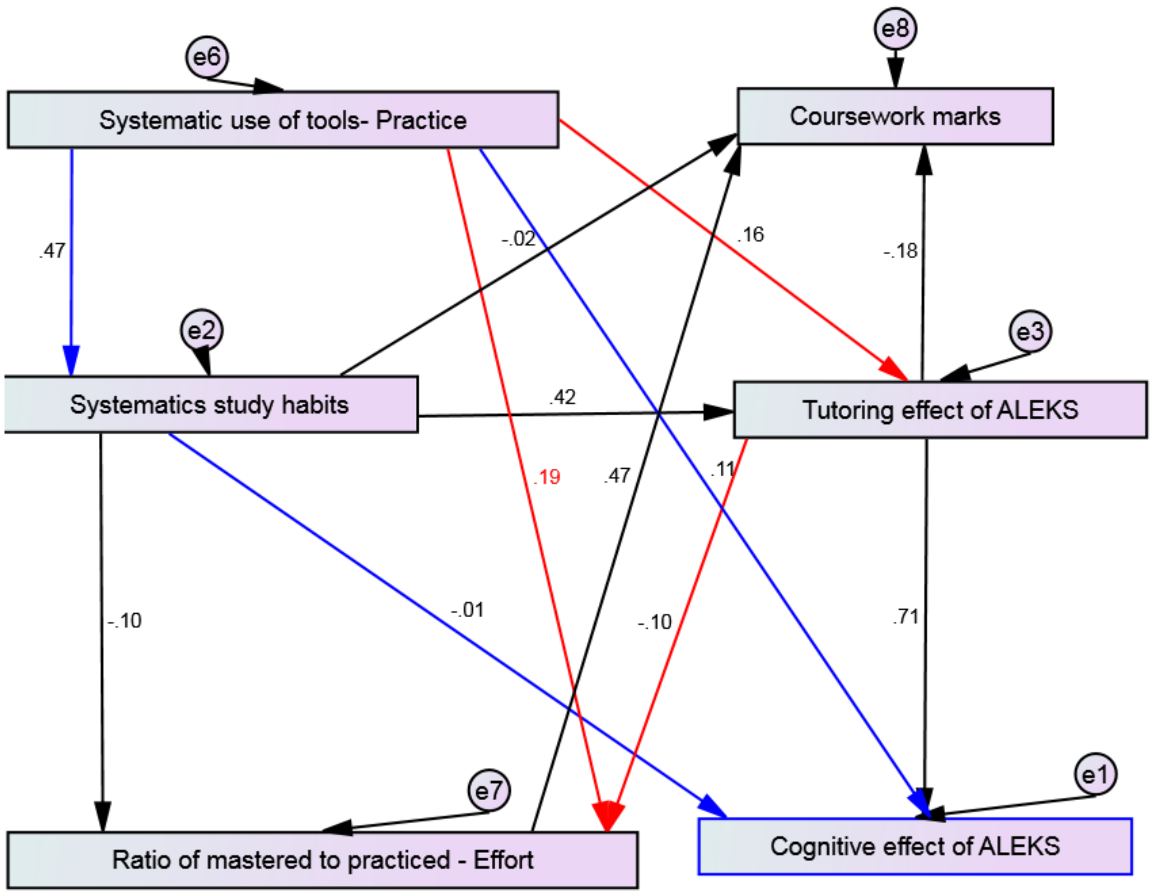
Figure 4.7: Path model for hypothesis 7



There is a statistical evidence to reject the null hypothesis which supports the claim of the alternate hypothesis, that the variable *mtop* is a predictor of academic achievement attained by a student.

After testing each of the hypotheses separately, the goodness of fit of the composite path model was verified. After running the path analysis, standardized regression weights along all paths were obtained. These regression weights are shown in the following diagram. The AMOS output showing detail regression statistics with significance values is presented in the Appendix.

Figure 4.8: Path model showing regression weights on each path



In addition to the analysis of hypotheses in the path model, more exploration is done to find out similarities or differences of perceptions and study habits of students according to their cluster membership. The results of this exploration are given in the next subsection.

4.5. Integration of survey and ALEKS data

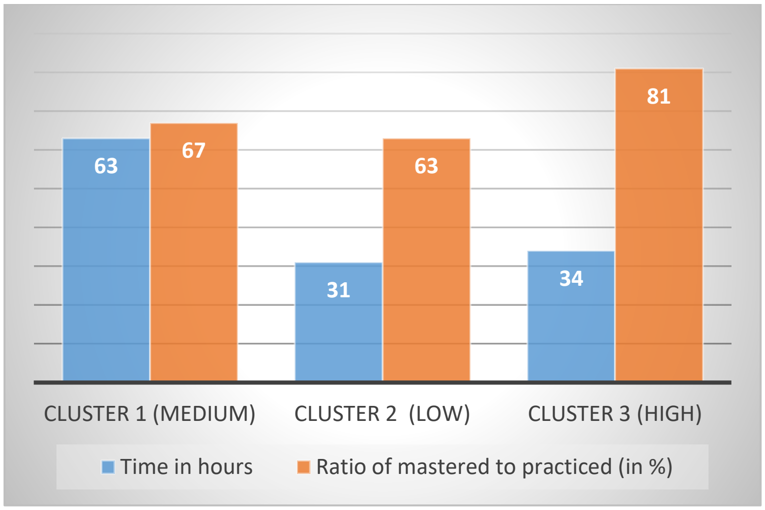
Student's actual efforts to master the course content are assessed by examining the two variables total time spent on ALEKS and the derived variable *mtop*. Students with similar effort levels are grouped together using cluster analysis.

Cluster analysis for exploring patterns

In order to determine which groups of students have similar learning profiles, a cluster analysis can be applied (Antonenko, Toy & Niederhauser, 2012; Cohen, Manion, and Morrison, 2011). Cluster analysis techniques are applied to group cases based on their similarity of certain attributes and hence these techniques can be used as a tool for exploratory data analysis. This exploratory analysis is done without any subjectivity; hence it provides an unambiguous view of profiles of students' learning behaviour (Dani, 2016). The two-step clustering method is recommended when variables are continuous and the number of clusters is not known a priori (Field, 2009).

In the current analysis, the two-step clustering method is applied to classify students based on their efforts (mtop) and time spent on ALEKS. The software detected three clusters by applying the Log-likelihood method. Students in cluster-1, on average, mastered 67% of the topics they attempted to master and spent 63 hours on ALEKS during the study course, whereas students in cluster-2 mastered 63% of topics and spent only 31 hours. Though the students in cluster-3 spent only 34 hours on average, they were able to master 81% of the topics they attempted to master. Refer to the Figure 4.9 below.

Figure 4.9: Mean values for Time and mtop for each cluster



The cluster profiles and distribution of cases among these clusters is presented in the Table 4.8 on the next page. Based on the values of *mtop*, students in cluster-2 exhibit the lowest effort level, the students in cluster-1 exhibit medium effort levels and the highest level of efforts are shown by the students in the cluster-3. These three clusters are labelled as *Medium*, *Low* and *High* respectively.

The cluster group labelled as *Medium* represents students who are hardworking but not high achievers whereas students in the *Low* group appear to be less motivated and low achievers. The group labelled as *High* has the smallest number of students (31%) and these students appear to be quick learners and high achievers. The Low and Medium groups have 33% and 36% respectively. Distribution of students in these clusters is more or less uniform.

As verified by the hypothesis **H7,** the variable *mtop* is a predictor of the variable course marks. It was found that the mean scores of course mark of Low, Medium and High groups are 57%, 74% and 77% respectively. This conforms to the findings reported in (Dani, 2015). A deeper investigation was done to examine if the students in these three clusters have similar or different perceptions and whether their study habits are different.

Table 4.8: Students' profiles based on values of *mtop* and time spent on ALEKS

cluster number-----→	**1**	**2**	**3**
	Cluster centres		
Total time spent in hours	63	30	34
Value of mtop = $\frac{number\ of\ topics\ mastered}{number\ of\ topics\ mastered}$	***67%***	***63%***	***81%***
	Medium	***Low***	***High***
Cluster size in % (and numbers)	36.4% (56)	33.1% (51)	30.5% (47)
Cluster Mean scores – perceptions			
Tutoring effect of ALEKS	1.8	2.0	1.8
Affect	1.8	1.9	1.9
Cognitive effect of ALEKS	1.8	1.9	1.9
Use of Tools in learning math	3.4	3.2	3.3
Beliefs about learning with tools	2.8	2.7	2.7
Mean scores – study habits			
Systematics study habits	1.8	2.0	1.8
External help	2.8	3.0	2.9
Systematic use of tools Practice	2.1	2.1	2.2
Persistence	3.2	3.0	3.0
Distractions	3.6	4.4	3.5

As mentioned before, variables obtained from the survey do not follow a normal distribution. The difference in their perceptions and study habits was examined by applying Kruskal-Wallis non-parametric test for 3 independent samples. The level of significance, α is set equal to 0.05.

The null and alternate hypotheses are set as follows:

$H8_0$: There is no difference in perceptions and study habits of students in three clusters.

$H8_A$: The perceptions and study habits of students in three clusters are different.

The p-value in each case is greater than 0.05 which indicates that there is no significant difference in the perceptions and study habits of students in these three clusters. As shown in the Table 4.8, the mean scores of their perceptions and study habits do not differ much. The similarity of mean scores between the two groups is tested statistically. The Table 4.9 summarizes the test statistic and its significance level.

Table 4.9: Result of 3-independent samples test about perceptions and study habits

			Perceptions		
statistic and its p-value	**Tutoring effect of ALEKS**	**Affect**	**Cognitive effect of ALEKS**	**Use of tools-Perceptions**	**Beliefs**
Chi-Square Statistic	4.281	3.090	2.405	1.484	.127
p-value	.118	.213	.300	.476	.938
			Study habits		

statistic and its p-value	Systematic study habits	Externa l help	Systematic use of tools-Practice	Persistence	Distractions
Chi-Square Statistic	1.572	1.966	1.120	2.262	.618
p-value	.456	.374	.571	.323	.734

It can be concluded that students in all groups have the same perceptions irrespective of their actual efforts.

4.6 Analysis according to the demographic variables

The Mann-Whitney-U test examines the statistical significance of difference between the overall ranks assigned by the participants in each categorical variable. Similarly, Kruskal-Wallis non-parametric test is required for three categories. These two statistical tests are applied for analyzing differences between groups of male and female students as well as students in three different courses. As mentioned in the chapter 1, the course number is a representative of duration of using ALEKS. The output of each test is given in the appendix. In the following subsections, the statement of each hypothesis and conclusion of data analysis is presented. Mann-Whitney U test was performed. (Level of significance α=0.05)

Difference in study habits of male and female students

$H8_0$: Null hypothesis: Study habits of male and female students do not differ significantly.

$H8_A$: Alternate hypothesis: Study habits of male and female students are not identical.

Results of Man-Whitney U-tests indicate that there is a significant difference between study habit1 (systematic study habit) and study habit 3 (habit of using ALEKS) of male and female students. (Sig 0.014 and 0.023 respectively). The mean rank for the variable systematic study habits as reported by male students is 115 and the same for female students is 94.

Table 4.10: Comparison of quartile values of study habits of male and female students

	Gender	Percentiles		
Study habits		25th	50th	75th
Systematic study habits	Female	1.4	1.8	2.2
	Male	1.6	2.0	2.7
Habits of using ALEKS	Female	1.8	2.1	2.8
	Male	2.0	2.5	3.0

A deeper exploration about quartile values reveals that more female students follow these two study routines very often than male students (Refer to the Table 4.10). 75% female students have a mean score 2.2 for the variable *systematics study habits*. Whereas only 50% male students have a mean score 2 for the same variable. Recall that lower score represents a higher frequency of following the study habit. Almost 75% female students follow systematic routine very often and only 50% male students follow systematic study routine. The percentage of female students following systematic study *very often are* higher than male students. It can be concluded that male students need to be encouraged to follow systematic study habits more often.

There was no difference in other three study habits of male and female students, which are *persistence, distraction and habit of seeking external help*. The p-value for each of these tests are found to be 0.9, 0.9 and 0.4 respectively. This similarity in the two groups can be attributed to their neutral responses indicating that both groups follow these habits sometimes.

Similarity in the perceptions of male and female students is examined by setting the following hypothesis and applying the same test.

$H8_0$: Null hypothesis: Perceptions about the effect of ALEKS of male and female students do not differ significantly.

$H8_A$: Alternate hypothesis: Perceptions about the effect of ALEKS of male and female students are different.

Results of Man-Whitney U-tests indicate that male and female students have different perceptions about *tutoring effect, effect on interest in mathematics and cognitive effect* of ALEKS (p-value= 0.000 for each of these factors). The mean rank for the variable tutoring effect of ALEKS as reported by female students is 90 and the same for male students is 124, whereas the mean rank for the variable cognitive effect of ALEKS are 92 and 119. The mean rank for the variable Affect reported by female students is 91 and that reported by male students is 123. These rank values indicate that female students feel strongly about the effects of ALEKS on their learning than the male students. The perceptions of male and female students about the use of tools and beliefs about learning with tools are not statistically significant. (p- value= 0.3 and 0.4 respectively). The mean value of this factor was found to be equal to 2.6 and 2.8 for female and male students. Both groups are neutral about how to learn using tools.

Difference in study habits according to duration of using the tool

$H9_0$: Null hypothesis: Students use the tool ALEKS in the same way irrespective of their duration of experience of tool usage.

$H9_A$: Alternate hypothesis: Students patterns of using the tool change with the duration of experience of tool usage.

Results of Man-Whitney U-tests indicate that there is no significant difference between study habit 3 (habit of using ALEKS) among students who have been using ALEKS for one, two or more than two semesters. (Sig 0.455).

Impact of duration of use on perceptions and beliefs

$H10_0$: Null hypothesis: Students' beliefs and perceptions about learning with ALEKS are same irrespective of the duration of use of ALEKS.

$H10_A$: Alternate hypothesis: Students' beliefs and perceptions about learning with ALEKS change as the duration of use of ALEKS changes.

Since the p-value indicated in the Table 4.11, it can be concluded that perceptions about four of the five factors do not differ among students from three different courses. The results of Kruskal-Wallis-tests indicate that there is a significant difference in the beliefs about learning with computer tools among students who have been using ALEKS for one, two or more than two semesters (p-value=0.05). But students' perceptions about tutoring and cognitive effect and as well as its ease of use do not differ according to the course number. This implies that students in all three courses find ALEKS easy to use and think that due to use of ALEKS their interest in mathematics has increased. Refer to the Table 4.11 given below.

Table 4.11: Comparison of perceptions according to the course number

Statistic and p-value	Perceptions about tutoring effects of ALEKS	Perceptions about usability and its effect on interest in mathematics.	Perceptions about cognitive effect of ALEKS	Perceptions about use of computer tutors in learning Mathematics.	Beliefs about learning with tools
Kruskal-Wallis H	.524	2.851	1.731	3.935	10.563
df	2	2	2	2	2
p-value	.769	.240	.421	.140	.005

Students' perceptions about the tutoring effect of ALEKS do not change as the duration of use of ALEKS increases, which means ALEKS is perceived as a useful tutoring tool from the beginning of its adoption. As described in the chapter 3, the factor belief about learning with tools is a calculated as the mean of its constituent items, such as *It is not necessary to solve each problem step by step*. Further cross-tabulation and Chi-square analysis was done using two variables, the course number and the constituent items of each factor. This analysis revealed that students' opinion about *It is not necessary to solve each problem step by step* are different. More students in M030 disagree with this statement than students in M010 and M020.

4.7 **Predictors of tutoring effect of ALEKS**

As noted in the section 4.3, three factors *Affect, beliefs about learning with tools and use of tools in general* are hypothesized to predict perceptions about tutoring effect of ALEKS. A simple correlation analysis is carried out to examine associations of these variables with the variable *tutoring effect of ALEKS*. Refer to the following table 4.12 for the summary of correlations between these factors.

Table 4.12: Correlation between factors

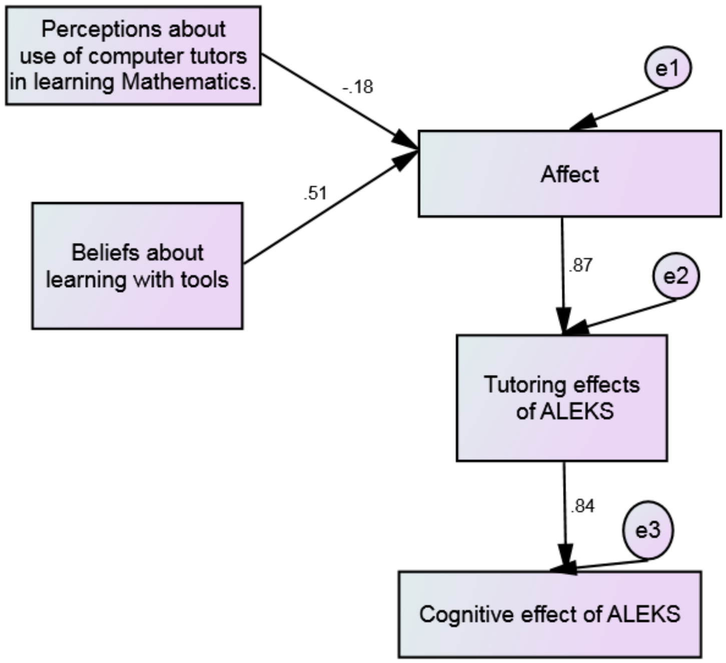
Factors \ Factors	Beliefs about learning with tools	Perceptions about usability and its effect on interest in mathematics.	Perceptions about use of computer tutors in learning Mathematics.	Perceptions about tutoring effects of ALEKS
Beliefs about learning with tools	1	.211**	.323**	.228**
Perceptions about usability and its effect on interest in mathematics.	.211**	1.000	-0.037	.682**
Perceptions about use of computer tutors in learning Mathematics.	.323**	-0.037	1.000	-0.033
Perceptions about tutoring effects of ALEKS	.228**	.682**	-0.033	1.000
**. Correlation is significant at the 0.01 level (1-tailed).				

Kendall's tau_b test to examine non-parametric correlation was performed. As it can be seen from the Table 4.12, the factor *Affect* has a strong, positive and significant correlation with the factor *tutoring effect* of ALEKS. It implies that, students who find ALEKS easy to use also think that it is an effective tutor.

Another factor *Beliefs about learning with tools* has a significant, but weak correlation with the factor *tutoring effect.* It can be interpreted that irrespective of their views about how to learn using some other tools, their perceptions about the effectiveness of ALEKS are positive. Whereas their perceptions about learning with tools in general has no correlation with their perceptions about the effectiveness of ALEKS. They may not possibly have favorable perceptions about learning with tools in general, but they may have positive perceptions about learning with ALEKS. It in fact indicates a mature way of responding as it indicates that the students do not want to generalize their experience of learning with one tool to their experience of learning with another tool.

In order to confirm the associations and their strength, another multivariate model is designed using the software AMOS. The following model in Figure 4.10, shows higher standardized regression coefficients which are significant.

Figure 4.10: Multivariate model showing association among factors



The fit of this model is examined from the AMOS output. It is found that the Chi-square statistic value is 2.991 with a p-value 0.886. Both the NFI and CFI values are equal to 1. These statistic values indicate that the path model shown in the Figure 4.10 is acceptable and there is an evidence of causality among the variables as represented in the model. The standardized regression coefficients indicate that the factor Affect predicts the factor tutoring effect, which consequently predicts the cognitive effect of ALEKS. This statistical conclusion implies that if a student finds the ALEKS is easy to use and it develops interest in mathematics, the student's overall learning experience will be positive. Consequently, it will facilitate learning as well as the development of mathematical concepts.

4.8 Open ended questions from student's survey

In the last section of the survey, students were asked to name apps which they find useful. Only 10% of students responded to this question. They mentioned the same apps mentioned by the teachers. Also, many of them mentioned that they use ALEKS. In response to the question, *why they find these apps useful*, frequent reasons were given as easy to use, interactive, explains well. These responses did not reveal any new perspective or name of a different tool, which is consistent with the response to one of the survey questions: "I use the same app that my teacher uses", to which 80% responded positively.

4.9 Analysis of teachers' data

This subsection begins with the tests of normality on teachers' data as the choice of further tests depends on the distribution of variables (Cohen, Manion, and Morrison, 2011, pg. 600), which is then followed by the descriptive statistics revealing trends.

4.9.1 Tests of normality

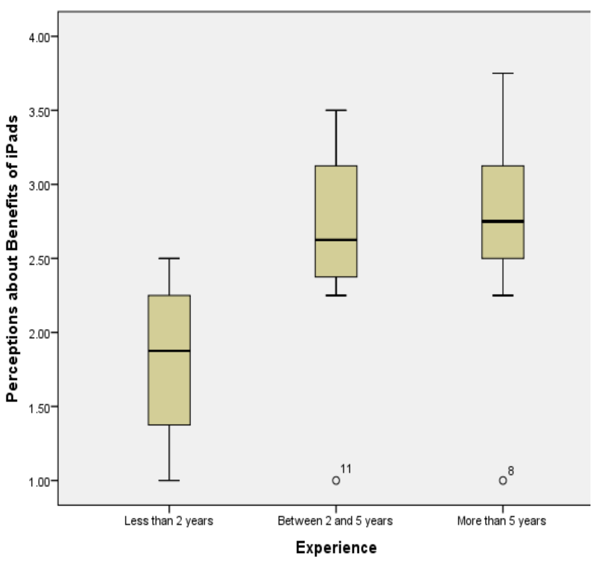
The first two factors from the teachers' survey measure perceptions about benefits and limitations of iPads in teaching mathematics respectively. For each of these factors, a mean score of responses of constituent items is calculated. Each mean score indicates respondent's overall perception about benefits and limitations. Kologorov-Smirnov statistic was applied on mean scores of these two factors. The Kologorov-Smirnov statistic value is found to be equal to 0.151 and 0.122 for factor1 (benefits) and factor2 (limitations) respectively, with p-value 0.2 for both. Since the p-value>0.05, it can be concluded that these two variables are normally distributed, consequently, parametric tests are applicable on these two variables.

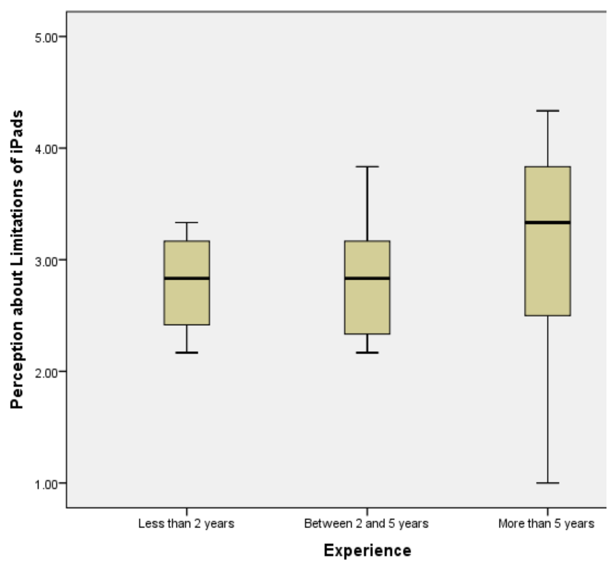
4.9.2 Descriptive statistics

In this section, the descriptive statistics for all factors is presented. The mean scores about perceptions about the benefits of using iPad is 2.5 whereas the mean score for limitations of iPad is 3. The mean score of frequency of using iPad for teaching tasks is 3.2 and the frequency of using iPad for administrative task is 3.6

The above mean scores indicate that teachers have positive perceptions about the benefits, but overall they are neutral about the limitations of iPad. Also, they use iPads for teaching tasks sometimes and very rarely for administrative tasks. iPads are used rarely for administrative tasks, such as marking attendance, due to the fact, that the institute provides a desktop computer in each classroom and laboratory. The teachers prefer to use them in the classroom for administrative tasks.

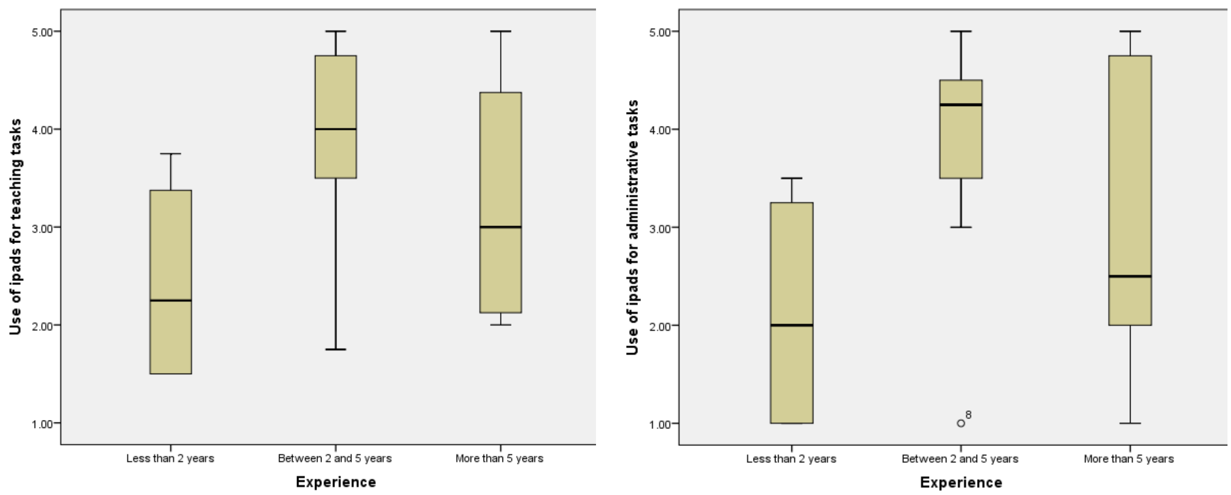
Figure 4.11 Teachers' perceptions about the benefits and limitations according to years of experience





These perceptions may differ according to years of experience. Therefore, box-plots of these scores according to the years of experience were constructed. It can be seen from the Figure 4.11; teachers with less than 2 years' experience have more positive perceptions about benefits of iPads than teachers with more experience, while more experienced teachers also think that an iPad has limitations as a teaching tool, than other teachers.

Figure 4.12 Frequency of iPad usage according to years of experience



Teachers with moderate experience of teaching with technology use iPads less frequently than the other teachers. Refer to the Figure 4.12.

Further parametric correlation analysis revealed that there is a strong, positive and significant correlation between perceptions about benefits and frequency of iPad usage for both teaching and administrative tasks ($r = 0.7;\ p = 0.001\ and\ r = 0.8;\ p = 0.000$ respectively). The statistical conclusion about the significance of correlation coefficient implies that teachers who have positive perceptions about the utility of iPad as a teaching tools are more likely to use it more frequently for both teaching and administrative tasks. They prefer to integrate iPads into all types of teaching activities.

4.9.3 Important features and their actual implementation in teaching

It has been noted by (Hoyles, & Noss, 2003; Trouche & Drijvers, 2010) that with the help of a handheld device like graphing calculators or iPads, students can focus on main mathematical concept and explore different problem solving strategies. Also with the help of these devices, teachers can demonstrate different visual representations, and they can provide students hands on problem solving activities. Students can learn anytime, anywhere and work in groups using these mobile devices. For each of these features, teachers were asked to provide their rank based on the perceived importance of each of these features in teaching mathematics. They also reported how often they are actually implementing each one of these features. The two variables *assigned rank* and *frequency of implementation* were analysed together to investigate if there is any gap in the intended use and actual use of iPads.

Mean and modal rank assigned to each feature was calculated as shown in the Table 4.13. Lower value of the mean or mode indicates that the feature is perceived as more important.

Table 4.13: Overall rank for each feature

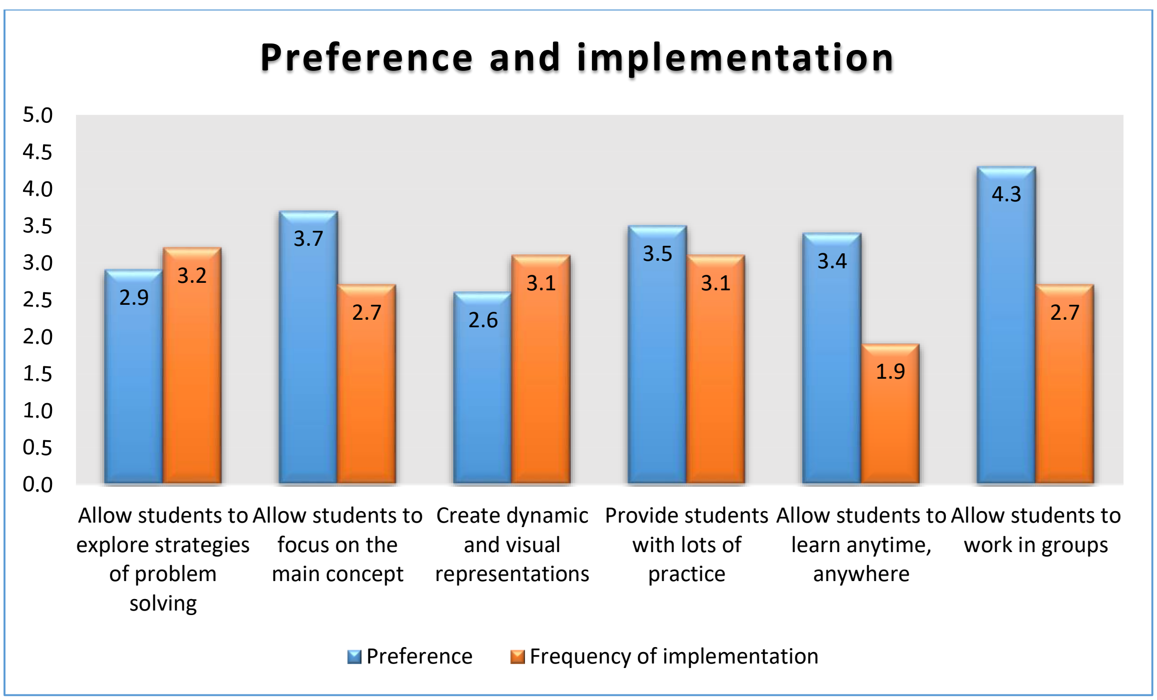
Statistic	Allow students to focus on the main concept	Allow students to explore strategies for solving problems	Create dynamic and visual representations	Provide students with lots of practice	Allow students to learn anytime, anywhere	Allow students to work in groups
Mean	3.7	2.9	2.6	3.5	3.4	4.3
Mode	2	2	3	2[a3]	5	6
Overall rank	5	2	1	4	3	6

[3] Multiple modes exist. The smallest value is shown

It can be seen from the Table 4.13, that the modal ranks are not unique and cannot be used as a unique indicator therefore, overall rank was calculated based on their mean values.

From the above Table, it can be seen that the feature *Using iPads to create dynamic and visual representations* is ranked as the most important feature and *collaboration* is ranked as the least important feature. A mean score higher than 3 indicates that the feature is implemented rarely and a value lower than 3 indicates that it is implemented often, whereas a value equal to 3 indicates that it is implemented sometimes. The figure 4.13 demonstrates the overall rank and frequency of implementation of each feature. It can be seen from the following figure, that most often implemented feature is *mobile learning* and least often implemented the feature is *exploring problem solving strategies.* It can be seen that currently, most of the teachers from this institute are not able to integrate digital tools to *transform* learning.

Figure 4.13 Overall rank of each feature and its frequency of implementation

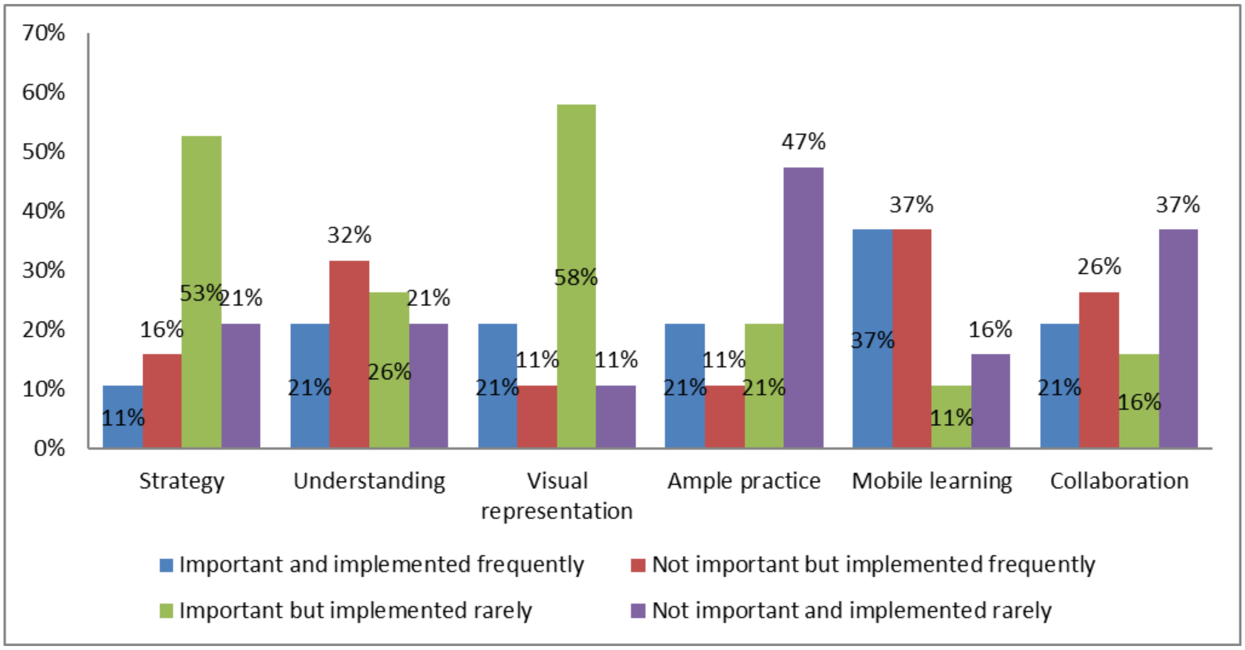


These features were further categorized as *Important* and *Not Important* based on their overall rank. Further, they were categorized into two different categories as *Implemented frequently* or *Implemented rarely* based on the frequency of their implementation. Cross-tabulation analysis of these categories together classified all these features into four exclusive categories, which *are Important and Implemented frequently*, *Important and Implemented rarely*, *Not Important and implemented frequently* and *Not Important and Implemented rarely*. It will be crucial to detect which features are reported as Important by most teachers but it is implemented rarely.

The majority of teachers reported that though they think that developing problem solving strategies and creating visual representations dynamically are important teaching practices supported by iPad, they are actually implementing them rarely. 16% and 11% teachers reported that they implement these two very often, but it is not important according to them. Whereas providing ample practice for problem solving and encouraging collaboration are implemented rarely, they are ranked as relatively less important features by the teachers. Refer to the Figure 4.13.

A cross-tabular analysis revealed the percentage for each as shown in the following Figure 4.14. It can be seen from this figure, that 58% teachers agree that iPad can be used to create visual representations and that is an important aspect for teaching mathematics effectively, but they are able to implement it rarely. This is an indication of a gap between intended use and actual use of iPads. A similar gap is observed in the implementation of using iPads for development of problem solving strategies. 53% teachers think that it is an important feature, but are rarely able to implement. Also the percentages corresponding to *Important and implemented frequently* are relative low except for the feature Mobile learning.

Figure 4.14 Importance and frequency of implementation



4.9.4 Topic wise preferred teaching method

Though teachers have positive beliefs about integrating tools in teaching this course, the extent to which they would integrate tools may vary according to specific topics in the course. In part IV of the survey, teachers reported their preferences to integrate use of an app to teach different topics effectively. As mentioned in chapter 3, teachers provided their answers on the scale of 1 to 4, 1 indicates no use of apps at all and 4 indicates teaching solely using some app. The following Table shows the mean value of each of these preferred methods specific to topics.

Table 4.14 Topic wise preferred method of teaching

Statistic	Solving equation in one variable	Solving a system of equations	Drawing line graphs	Perimeter/ area /volume	Application of percentages	Expon ents	Statis tics	Proba bility
Mean	2.11	2.42	2.68	2.63	2.32	2.21	2.68	2.68
Mode	2	2	3	3	2	2	3	3

Overall mean for each topic is between 2 and 3, which means all teachers think that a combination of traditional teaching method and use of technology is an effective teaching strategy to teach all of these topics.

The mean score for some topics such as Geometry, Statistics, probability, Line graphs is more than 2.6, which means teachers prefer to integrate digital tools extensively to teach these topics. These topics are based on the concept of multiple representations and it is expected that students develop an understanding of multiple representations. They are explained effectively with the help of dynamic visual representation and the mean scores shown in the Table 4.14 indicate that the teachers are well aware of the strength of digital tools. 75% teachers would like to teach these topics by combining traditional and contemporary methods in which there is high usage of digital tools, but none of them would like to teach completely using digital tools.

The teachers prefer to teach other topics, such as solving equations and systems of equations, exponents integrating digital tools moderately in their traditional method of teaching. 18% of the teachers reported that these topics are best explained using traditional teaching methods without any digital tool. Topics from algebra involve a number of symbols and development of these symbols as well as their interpretation needs to be developed. Some existing tools, such as a scientific calculator, may solve the equations and give the final answer, but may hide the intermediate steps, due to which students may not completely understand the reasoning and justification. The teachers' responses indicate that they know these limitations of the tools.

4.9.5 Open ended responses from teacher's survey

In this section, a summary of responses to the open ended questions is provided.

In response to the question "*which other apps do you use for teaching"*, teachers reported the following apps: Geogebra, Slopeslider, Desmos. These mathematics teaching apps are chosen by teachers because they can be used to create interactive lessons. Students can be encouraged to explore different representations of a mathematical concept with the help of these apps. Also other classroom management apps for creating formative quizzes and video lessons, such as *Nearpod, Socrative and ExplainEverything* are being used by teachers.

Only one of the participants expressed his views on the use of tools, which are as follows:

> *Technology in any form undoubtedly enhances student's learning if it is to be used in the right mix with the traditional approach. There should be proper planning and control on the use and accessibility.*

This view is consistent with the majority of other teachers' preferred method of teaching. Other respondents did not express their views.

Overall, the teachers in this institute would like to integrate technology in their traditional teaching methods, rather than replace traditional methods completely by technology.

4.10 Analysis of the observation data

As mentioned in section 3.13.1, a semi-structured format is used for collecting data from class observations in which important interactions in a mathematics class are coded numerically. Due to the semi-structured format and numeric coding, it is possible to find the frequency of occurrence of each interaction. These frequencies indicate intensity of events which are then presented in a graphical format.

Class-1, Class-2 were observed in the morning session from 9:00 to 9:50 am and 10:00 to 10:50 am respectively, whereas Class-3 was observed in the afternoon session from 2:00 to 2:00 pm. In all classes, students were polite and showed respect to their teacher and other students. It was noticed that some students in Class-1 reported late for the class, but tried to catch-up with the class activity, immediately.

Physical settings of all three classes were almost identical. Each classroom had a teacher's desktop connected to a digital whiteboard, which also served as the presentation screen. A high-speed Internet connection was available to students through a Wi-Fi connection.

The following demographic characteristics were determined from the pilot observation: *students' background, teacher's background, tool usage by teachers and students and learning environment.* Detail description of three classes specific to these characteristics is presented next. The three classes are labelled as class-1, class-2 and class-3 and respective teachers as teacher-1, teacher-2 and teacher-3.

Students' background

Students' demographic as well as background information about their English language proficiency and their overall academic ranking are compared. Class-1 had all male students in the age group of 17 to 25. Their English language proficiency was low. Whereas in class-2 and class-3 all students were females in the same age group and their English language proficiency was moderate, slightly higher than the students in the class-1. The students in the class-3 were enrolled in M030 course, which is designed for Engineering students and the students in class-1 and class-2 were enrolled in M010. All students in the class-3 were going to join the Engineering stream and had a strong aptitude for mathematics as compared to students in the other two classes.

Teacher's background

All three teachers had more than fifteen years of experience of teaching mathematics. All of them were conversant with the curriculum and the culture of the institute. The teachers of class-1 and class-2 had more than five years of experience of teaching mathematics using digital tools, but the teacher in class-3 had used tools in teaching mathematics only for five years.

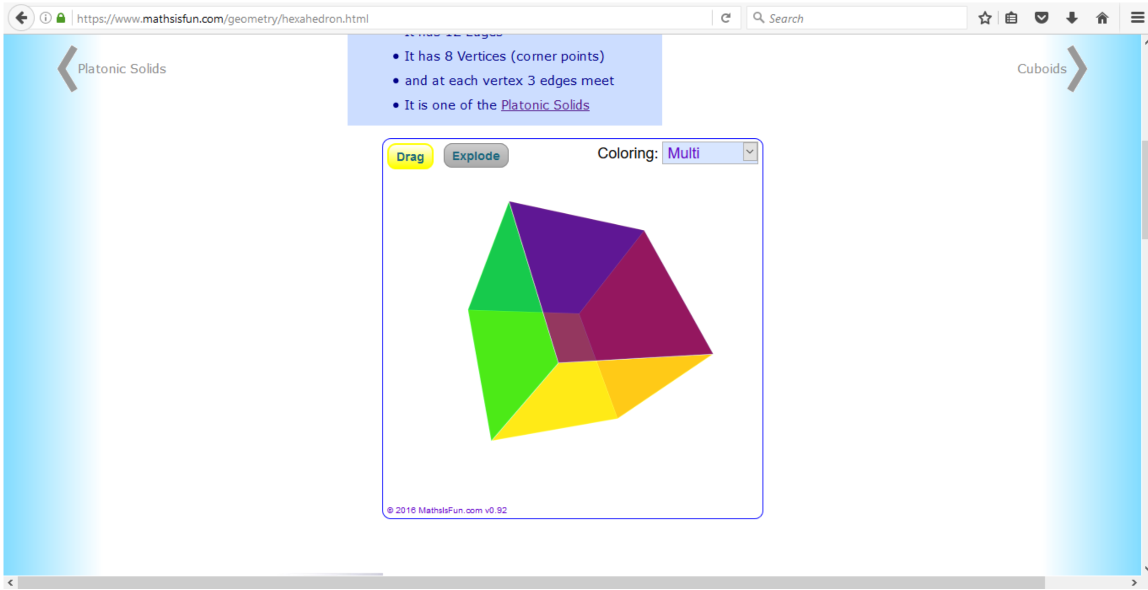
Use of tools

The topic covered in class-1 and class-2 was *properties of solid shapes*, *whereas* the topic in the class-3 was radicals and rational exponents. Accordingly, the teachers in class-1 and class-2 had planned to use interactive tools. The teacher-3 did not intend to use any interactive tool, but had planned to show presentation slides for explanation.

The teacher-1 used an interactive applet named *Shapes.* The properties of solid shapes were demonstrated with the help of this applet. The teacher-2 used interactive presentation tool *Nearpod,* which can integrate presentation slides, quizzes and web-based interactive applets. The teacher showed this presentation on her iPad, which was connected to the digital whiteboard through a wireless connection. This presentation was hosted on a website and the students could watch it on their iPads.

The teacher in class 2 used an interactive applet provided at the following URL: https://www.mathsisfun.com/geometry/hexahedron.html. The screenshot of the visual representation of one solid shape is shown below.

Figure 4.15: Interactive applet showing properties of 3-D shapes



During the class activity, students could interact with this applet. By spinning each shape, they could visualize all faces, vertices and edges of different 3-d shapes. At the same time, they completed their worksheets as they discussed with their group members. The teacher encouraged them to take notes while using the tool. Since it was a student-paced presentation, students were given sufficient time to think, discuss and reflect on their learning. Although they were expected to examine properties of only five shapes, some students explored information beyond the set task, which indicates their engagement in learning.

Similar presentation was shown in class-1 by the teacher using a different app, but students watched it passively as the teacher demonstrated properties of each shape on his iPad. The students in the class-1 did not have the same app on their iPads.

As defined in the chapter 2, the *semiotic potential* of a tool indicates the degree of support offered by that tool for learning mathematics. The web-based applet shown above had a better semiotic potential than the semiotic potential of the app used in the class-1. The web-based applet could provide students an experience of handling solid shapes virtually. It was effective in relating the terms, such as *vertex* with its physical property.

Students in the class-2 were able to explore the applet by repeated interactions with it and exploit its semiotic potential as contrasted with students in class-1. Though the teacher explained properties of solid shapes by spinning them, students in class-1 were not given the opportunity to do it themselves.

Its impact on their learning was noted from the students' follow-up problem solving activities. In class-1, students had to translate the terms in Arabic before solving a problem and in class-2, most of the students have learned their new terms from the visual demonstration provided by the applet and were ready to solve the set problems.

In class-3, the prime tool ALEKS was used by the teacher only to extract assessment questions, whereas students had the choice to refer to explanation provided on ALEKS using their iPads. The students primarily used their cognitive resources, such as prior knowledge, and a scientific calculator only.

Learning environment

In class-1, the students worked individually whereas in class-2, the teacher had set a collaborative activity. In class-2, teacher made sure that students wrote their notes as they interacted with the tool, whereas in class-1, the teacher did not insist on taking notes, as a result students did not take notes. In class-3, the though teacher did not instruct explicitly, the students were taking notes as the teacher explained by writing on the whiteboard. It appeared that these students were motivated and interested in learning.

Overall learning environment of a student in class-2 included a variety of tools, such as, interactive applet, iPads, study notes, along with the teacher and peers. The learning control was transferred from teacher to students very quickly in class-2. All resources used during classwork activity in class-2, were available to students after class time, which means they could revise later anytime, anywhere as is expected in mobile-learning. The teacher in class-1 used the tool to support whereas the teacher in class-2 used it to extend learning. In class-2, the teacher embedded the quizzes and the interactive applet in the presentation due to which students could easily move between learning and assessment mode.

It was observed that there were more *Teacher-Students* interactions in class-3 than in other two classes. The students appeared passive and less enthusiastic, but in the end, most of them had completed their classwork assignment successfully. Probably, they needed some more challenging work to increase their interest in learning. The students in class-1 were engaged in the learning activity only in the first half of the class, whereas in class-2, students retained their interest and engagement for the complete duration of class. There were more *Student-student* and *student-tool* interactions observed in class-1 and class-2 than in class-3. The learning environments in class-1 and class-2 were student-centered as opposed to the teacher-centered learning environment in class-3.

Observed activities

During interactions with the students in class 3, the observer found that they, struggled with the concept of simplification of rational exponents; for example, rewrite $2^{\frac{4}{3}}$ as $2 \times \sqrt[3]{2}$. They were not able to link two concepts together: one concept was about the meaning of $\sqrt[n]{x}$ as the nth root of x and the other concept was about simplification of the improper fraction $\frac{4}{3}$ as $1\frac{1}{3}$.

As the observer talked to one of the students, it was revealed that they have always used a calculator and simplified a radical number in a decimal form since their secondary years at school. The reason for their underdeveloped basic concepts of fractions and radical numbers could be due to wrong and untimely use of the scientific calculator in high school years. Probably, in high schools, students were trained to use the calculator for simplification and they continued to use it as a master.

Too much exposure and dependency on calculators which they had experienced in high schools, may have developed only procedural skills without complete conceptual understanding of exponents. With procedural skills they are able to evaluate a numeric approximate answer for an expression like $\sqrt[3]{32}$ with the help of a calculator. When expected answer is a simplified radical expression and not an approximate number, students need to develop both the procedural and conceptual understanding. According to the semiotic theory principles, mere procedural use of a device may not develop understanding of mathematical symbols.

Foundation year courses are designed to support students in the process of transition from high school to university level courses. One of the expectations in this transition process is that students must develop ability of comprehending and conceptualize abstractions. For example, during secondary years, students may have conceptualized the meaning of symbols such as $\sqrt{16}\ or\ 2^3$ as a procedure to evaluate exponents. As they progress to post-secondary level, they must interpret the symbol $\sqrt[n]{x^m}$ as a procept to be able to produce the answers in radical expression form.

After noticing students' difficulties, the teacher used the same scientific calculator to explain simplification of rational exponents. The teacher demonstrated simplification of the rational number which appeared as exponent in the expression, into a mixed number. The integer part of the mixed number appeared as the integer power outside the radical sign. Now the symbols were explained in the context which developed deeper understanding of expressions with rational exponents. Still in this case, scope of using a tool (calculator) is limited to the support level only. The tool was not used by the teacher to extend or transform learning. In spite of these minor hurdles, students in this class were able to achieve their goal during the class activity, because these students had overall higher academic standing than those in other classes. The tool accelerated their learning.

Interactions observed in class-1 are comparable with those in class-2. But interactions in class-3 are not comparable with those in other two classes for two reasons. The first reason is that the teacher did not use any supporting tool other than ALEKS in class-3 and the second reason is that students in class-3 had a higher academic standing than the students in the other two classes.

A summary of key points and demographic descriptions of the classes is given in the Table 4.15.

Table 4.15: Summary of demographic data collected from observations

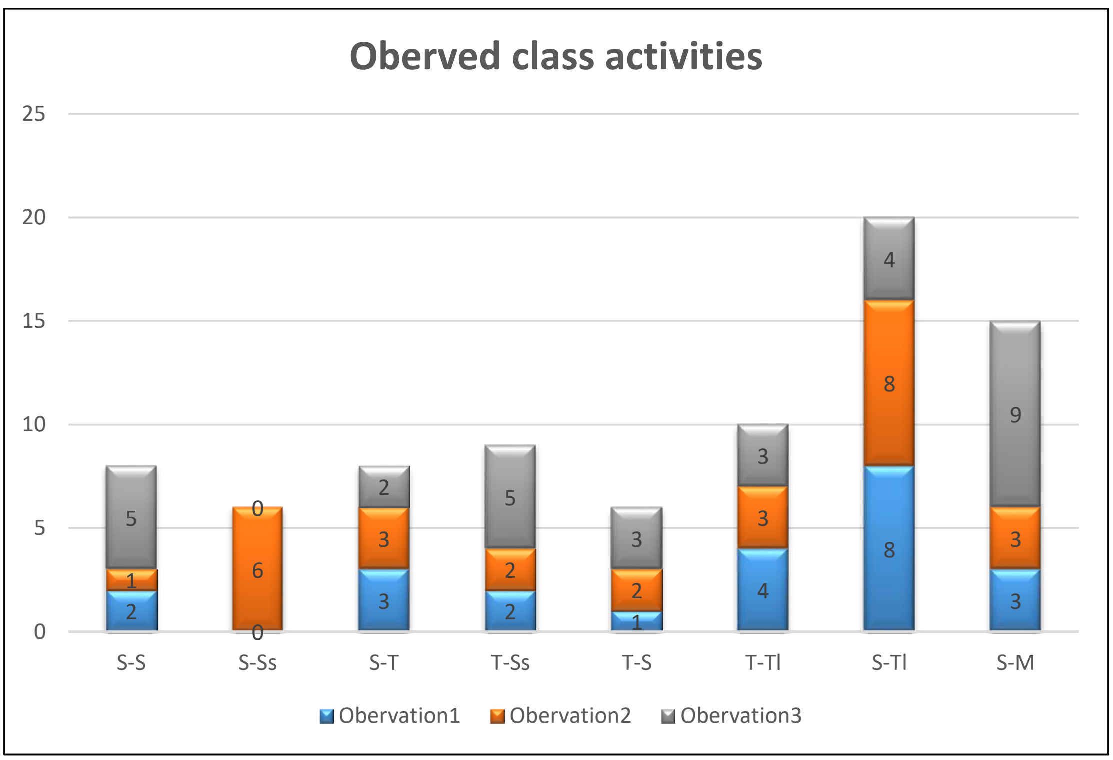
Description of observation criteria	Observation -1	Observation -2	Observation -3
English language proficiency	Low	Moderate	Moderate
Overall academic standing	Medium	Medium	High: All students pursuing Engineering major and had a strong aptitude for mathematics
Digital Tools used by the teacher	Applet named *Shapes*	Interactive presentation tool Nearpod, Interactive applets hosted on the website www.mathisfun.com	PowerPoint presentation
Physical Tools used by students	Ipads and mobile phones to access online dictionary	iPad, formula sheet, scientific non-programmable calculator	iPad or laptop, formula sheet, scientific non-programmable calculator
Digital tools used by students	ALEKS	ALEKS, Interactive presentation tool Nearpod, Interactive applets hosted on the website www.mathisfun.com	ALEKS
Class set up	No collaboration	Collaborative	No collaboration
Transition from lecture mode to student-activity mode	Students' engagement level increased almost 20 minutes after the class started	Students started participating actively within first ten minutes after the class started	Not apparently observed in the first 30 minutes, but towards the end of the class, students had solved all the classwork exercises.

Achievement of goals (as observed)	80% of students completed 70% of class exercises correctly.	100% students completed all classwork exercises correctly and received feedback about it.	90% of the students completed all classwork exercises correctly and received feedback about it.

From the above summary, it can be seen that the overall rate of achievement of expected learning outcomes was the highest in case of class-2 and-3 and it was the least in case of class-1.

The following figure shows frequencies of different types of interactions observed in three classes.

Figure 4.16: Frequency distribution of interactions observed in three classes



As it is shown on the above graph, in class-3, there are fewer interactions of students with the tool than those in other two classes, but they had more interactions with other tools, such as their study notes and calculator. Also, there were more *teacher-students* interactions in class-3 than other two classes. Due to integration of tools, the learning environment in class-1 and class-

2 was student-centered unlike teacher centered environment in class-3. Though the learning environment in class-2 was student-centered, there was no evidence about attaining the learning aim of that session. It must be examined which parameters could have possibly enhanced learning in case of class-2. Two distinct features were noticed, the first is students' direct interaction with the tool and the second is student's collaboration with peers.

Though students in class-3 interacted with ALEKS less frequently, they interacted with other tools, such as, their notes and scientific calculator more frequently. It can be summarized from the above notes, that the integration of the main tool ALEKS only may be sufficient for students who have a higher academic standing and a positive aptitude for mathematics. These students knew the value of mathematics in their chosen degree and are motivated to learn. But for average or weak students more interactive tools and different teaching strategies, such as collaboration, must be incorporated in teaching mathematics, in order to increase their interest and motivation.

4.11 Summary

In this chapter, a detailed description of various data analysis methods and their results was presented.

From the analysis of students' survey data, it was found that a high percentage of students agree that ALEKS is an effective learning tool. The study habits *systematic use of the tool* and *systematic study habits* have a positive impact on students' learning.

Three variables are extracted from ALEKS data logs, *total time spent on ALEKS*, *total number of topics practiced* and *total number of topics mastered* are indicators of student's actual efforts of mastering course content. The variable derived as a ratio of *number of topics practiced* and *total number of topics mastered* is a strong predictor of final grade in the course. Three groups of students were detected by applying the method of two-step clustering based on similar effort levels. The mean scores of each perception factor and study habit factors are not significantly different among these three clusters. Whereas the difference in the perceptions about effectiveness of ALEKS is found to be statistically significant between groups of male and female students.

It is found that the teachers from the chosen institute are willing to integrate digital tools in teaching mathematics but prefer to teach only some of the topics using digital tools. According to many teachers, digital tools can be used effectively for development of metacognitive strategies. They would prefer to use digital tools for providing *knowledge about different problem solving strategies* and fostering their *ability to choose the appropriate problem solving strategy.* At the same time, these teachers have reported that they are not able to use such tools for development of these abilities more often.

Some teachers are including other digital tools, such as spreadsheets, to supplement ALEKS based teaching. High level of student engagement in learning was noticed in classes where interactive tools were included to extend teaching whereas it was found to be low in classes where teacher used digital tools only to support their teaching.

5. Discussion

Findings from the analysis of all four research questions were presented in the previous chapters. A holistic view of existing research and new findings as well as recommendations and future directions of this research are presented in this chapter. The chapter has four sections, evaluation of ALEKS, research findings, recommendation, limitations and future direction.

5.1 Evaluation of ALEKS as a pedagogical tool

Discussion about the main tool used in this study, which is the intelligent tutor ALEKS and its impact of student's learning is presented in this section. This evaluation will provide an insight into limitations of the tool for teaching and can provide directions for development of teaching and assessment strategies to improve learning and teaching.

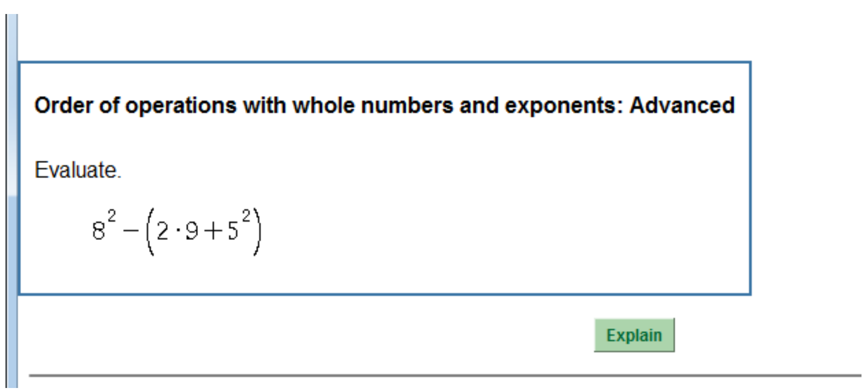
An intelligent tutoring system (ITS) is designed with the expectations that it can mimic abilities of a human tutor. As noted in chapter 2, an expert human tutor has knowledge about the subject and knowledge about how to teach it as well as a human tutor can adjust the pace or style of teaching according to student's response. Accordingly, an intelligent tutoring system should be able to present the domain knowledge for which it should have a component for storage and manipulation of domain knowledge. It should have the knowledge of teaching strategies, as well as knowledge about each student's learning ability and difficulties. It has one component which maintains information about student's knowledge as well as every student's learning history. The third component is required for communicating, which can respond to student's request as well as deliver content, hints and feedback. A separate control component coordinates all learning, teaching and communication activities. Features of the intelligent tutoring system ALEKS are evaluated on the basis of the four criteria as recommended by (Mark, and Greer, 1993).

Component of domain knowledge

ALEKS has developed predefined modules for basic and intermediate courses in arithmetic, algebra, geometry and statistics. Curriculum leaders can customize the curriculum as required and design a template for the course. Once a course is designed, ALEKS provides the course content through examples, explanation and problem solving strategies in a textual format. Hyperlinks are embedded within the explanations which can be used for getting additional explanation, such as mathematical definitions. It also uses interactive applets for drawing graphs of linear equations by providing easy to use drawing tools and interfaces. The domain knowledge component of ALEKS is sophisticated as required for higher education courses. There are no issues with the accuracy of the content but some issues are noticed in the presentation of the content.

In some examples, the representation of numeric expressions is represented ambiguously. The system uses of the symbol '.' to represent multiplication of two numbers, which is read by most of the students from the chosen population as a decimal point.

Figure 5.1: Ambiguous representation of numeric expressions in ALEKS



This misinterpretation can be possibly due to students' under-developed conceptual understanding of symbols in the secondary education. For the majority of students, symbol sense is not developed when they join the foundation year program, and such ambiguous representation is confusing for them. But ALEKS representation makes it more complicated and does not explain how to interpret such symbolic expressions. It can be said in this context, that the degree of support provided by ALEKS knowledge component is minimal. It can be improved by adding explanation about all variations in symbolic expressions and support the explanation by counter examples.

Component of teaching

The component of teaching built in ALEKS is responsible for presenting a problem and its solution as well as the contents. An expert human tutor not only knows how to solve a problem, but also knows which concepts could be difficult for students and how to teach those concepts effectively. Based on the knowledge about subject, student and effective ways of teaching, a tutor is able to present the necessary strategies or hints to the student (McArthur and Stasz, 1989). ALEKS provides hints while solving some topics but not all. For example, it provides a hint when the final answer is not rounded at the correct place. On the other hand, when a student counts the elements in a set from a Venn diagram incorrectly, no hint is provided. Only the feedback on the final answer is given.

Many fundamental concepts in Geometry can be explained effectively with the help of visualization. Also as reported in the teacher's survey, the majority of teachers would prefer to teach Geometry with the help of visual presentation. This expectation is not met by ALEKS. Providing dynamic and interactive visualization is possible with a computerized teaching environment, but ALEKS uses static representation for explaining such concepts, which is no better than explanation given in any paper based textbook. This is under-utilization of the power of dynamic representation of digital media.

Any intelligent tutor system is expected to possess the ability to create individualized instructions based on student's background knowledge, level of cognitive development and learning style. (Ackerman, Sternberg and Glaser, 1989 as quoted in Mark and Greer, 1993). As noted in chapter 2, ALEKS has the ability to create individualized sequence of topics for each student but the instructions do not account for individual learning styles. It relies only on visual and textual representation of content which may not be appropriate for students who prefer to learn by listening rather than reading. Although in the current version, there is a provision for listening to audio explanation for some topics, it is still not accessible to all students. This shortcoming can be overcome by uploading videos. Currently, the teachers in this institute have already adopted this strategy.

The functioning of the teaching component is not completely sophisticated as yet, which means the teacher will have to provide supplementary material. It leads to a conclusion that ALEKS is best utilized in a blended learning style rather than in a completely online learning style.

Component of student knowledge

The component of student knowledge of ALEKS is responsible for the diagnostic assessment and modeling of subsequent learning profiles of each student. It also maintains logs of all learning activities including topics attempted and topics mastered. For each student, it also records student's action indicating if the student is learning a new concept or reviewing previously learned concepts or taking a *progress test*. Refer to the Figure A-1 in the Appendix-1.

Periodic progress tests are administered by ALEKS to detect retention of knowledge. As found in (Dani, 2015), there was no evidence if these progress tests are actually facilitating learning. Probably, ALEKS is not successful in providing learning through assessment to all students.

After each progress test, the previous learning score is adjusted. This mechanism provides accurate and up to date model of student's learning. Students can see their up-to-date progress on the dashboard of the interface. This is one of the most sophisticated features of ALEKS, but there is no evidence if students are using all features to monitor their own progress.

Communication component

The communication component is responsible for providing quality interface to students so that a student can understand how to use the program and avoid any kind of misinterpretation of any given information. Some issues of misinterpretation are noted in the interface of the version that was used in this study. Since ALEKS is designed on the principles of knowledge space theory, a student is not able to solve problems unless he or she has mastered the pre-requisite topics. There are not clear instructions presented to students on the home screen of the system about this fact. This can be avoided with an improved representation, in which the student can see the list of all topics. The topics which are not accessible yet can be shown without a hyperlink to their detailed explanation.

In the current version the software has bilingual interface, one in English and the other in Spanish. It also embeds a calculator which is accessible to students in certain topics. The presentation of fractions, radicals and exponents is consistent with the presentation used in any textbook. Some applets or apps represent exponent like 2^3 as 2^3, which is confusing for students, whereas ALEKS represents it as 2^3. This is a good feature of representation.

ALEKS provides individualized learning support and scaffolding, which encourages weak as well as introvert students. Students who normally may not feel comfortable to discuss their shortcomings or mistakes with their teacher in a face-to-face session, may not feel the same in an individualized learning environment. This may motivate them to improve their learning by practicing at their own pace.

After this evaluation, it is found that ALEKS is a good tutoring system for mastering topics. But there are some features which are not built in the system. With careful planning of assessment strategies, these features can be incorporated in mathematics courses.

Gitsaky and Robby (2015) did empirical investigation about impact of ALEKS on student's academic success and found that after including ALEKS in the foundation mathematics curriculum the rate of failure decreased. Their research was based only on ALEKS data logs and was in a different curriculum context. Within the curriculum context of studies presented in (Dani,2015; Gitsaky and Robby 2015), the assessment strategies incorporated only ALEKS administered comprehensive tests and the duration of each cycle was for 16 weeks. Based on the recommendations made by (Gitsaki and Robby, 2015), the curriculum delivery mode as well as the assessment strategies were redesigned. In the previous delivery of curriculum, students were expected to master 85% of the course content at their own learning pace. There was no need of classroom teaching as the teachers were expected to provide support to struggling students. This mode of curriculum was more like completely web-based mode.

But there were some drawbacks with this assessment strategy. Questions included in the ALEKS administered comprehensive tests are not identical for all students, which means students' learning outcomes were not assessed uniformly. Gitsaki and Robby (2015) further recommended to make changes in the assessment strategy. Consequently, in the current curriculum, assessment strategies were amended by including uniform assessments.

Within the previous curriculum framework, in an attempt to complete minimum number of topics to pass the course, students often practiced mechanically. There was no evidence of sustained and deep learning. The impact of students' random mode of learning was examined by Dani (2016). It was reported in this research that students who do not organize their learning activities consciously, may not be able to retain mastery of their learning. Whereas, students who organize their learning activities are able to retain it. As advocated by the theory of self-regulated learning, students demonstrate control over their learning (Georgia and Symeon, 2010). Identifying and setting learning goals and monitoring own progress, are examples of self-regulatory habits, which can be nurtured in an online learning environment. Students need to develop self-regulatory study habits which can help them retain their learning (Dani, 2016).

ALEKS provides this flexibility of setting goals and monitoring them, but in the current curriculum delivery framework, teachers and students are expected to follow the common goals set by the curriculum leader. Students or teachers are not provided opportunity to exercise use of this feature of ALEKS for their personal development.

It also provides target based assessments. Teachers can set the targets for mastering a certain number of topics within specified time period. Such assessments grade students for achieving the target. But there is no evidence found about such assessment practices adopted by teachers in the current institute.

ALEKS avoids multiple choice questions, which means students cannot guess their answer. Though it is expected that students need to solve each problem, they have to provide their final answer without showing the intermediate steps of problem solving. Though individual support is provided by intelligent tutors like ALEKS, opportunity to learn through reflection is not provided. (Collins and Brown, 1987 as quoted in McArthur and Stasz, 1990). When students are encouraged to explain their strategy, it gives them opportunity to reflect on their thinking. It strengthens their learning as well as meta-cognitive skills. Aleven, and Koedinger (2002) claimed that when a feature of self explanation was built-in their tutoring software, it led to enhancement in student engagement as well as learning. This feature of showing steps or demonstrating metacognitive skills is not available in current version of ALEKS.

This evaluation of ALEKS combined with research finding will lead to recommendations for curriculum changes,

In the next section, overview of results obtained from data analysis is presented.

5.2 Analysis of research questions 1 and 2

Research questions 1 and 2 are restated here for the sake of continuity.

RQ 1: How do students perceive the suitability of iPads with appropriate software or app, to learn mathematics?

RQ 2: How are students using iPads in studying mathematics in the classroom and outside the classroom?

Though the first two research questions were set out as open ended questions, more intricate and meaningful associations among some variables were revealed. This investigation was possible due to high reliability and validity of the survey instruments used for assessing study habits and perceptions.

There are two important factors in this survey instrument, which measure student's perceptions about the tutoring effect of ALEKS and their perceptions about cognitive effect of ALEKS. The first one measures student's opinion about the support provided by ALEKS to master the course content. This support is measured on the basis of adequacy and variety of questions administered by ALEKS to develop mastery of a conceptual unit as well as the hints and feedback provided on their learning. The second factor measured student's opinion about support provided by ALEKS in developing their understanding of mathematics. This was assessed by measuring their satisfaction about the explanation and illustrations provided by ALEKS.

It was found that 72 % of students agree that ALEKS is effective as a tutor, easy to use and they also agree that use of ALEKS had a positive impact on their interest in mathematics. Students also think that ALEKS plays a major role in development of their mathematics knowledge. A strong and significant correlation was found between their perceptions about tutoring effect and cognitive effect of ALEKS, which indicates that the development in the knowledge of *use of tool* facilitated development of subject knowledge and as the subject knowledge developed students developed procedural proficiency of using the tool. This finding conforms to the theory of instrumentation illustrated in Figure 2.1.

This finding also confirms the findings of Dani (2016). From the investigation of a small sample data from ALEKS, it was found that students who have sound prior knowledge can interpret the hints and act accordingly better than those who do not have sufficient prior knowledge. In this context, it can be stated that when ALEKS developed their conceptual understanding, students were more receptive of the feedback and could accelerate their learning. The source of prior knowledge could be the learning activities in the classroom as observed in the investigation of research question 4. This finding points once again in the direction of blended learning, where students have face-to-face teaching as well as they can study online.

Overall, students reported that they find learning with iPads and with ALEKS easy and effective. But majority of them prefer to learn with ALEKS under their teacher's guidance. A very few students explored different apps to support their learning. Their habit of using a tool in a limited scope as instructed by the teachers indicates that the tools is their master. Their use of a tool is within a scope of *tool as a master* or *tool as a servant* only (Geiger, 2005). This ability to use a tool in a limited scope can be attributed to the fact that this is their first year of learning in a foreign language and learning with a digital tool. It can be anticipated that as their proficiency in English language as well as proficiency of tool usage will improve, their ability to learn with technology may also mature. It can be anticipated that they will be able to use tools as their servant or partner.

The students from the chosen institute have positive perceptions about affect and beliefs about learning with digital tools, which increases their level of engagement in learning. Though there is no evidence to claim that these perceptions have positive influence on students' study habits, or academic achievement, their contribution in motivating students and fostering student-centered learning cannot be overlooked.

Affect is a psychological construct which can reflect opinion about learning mathematics using tools. In the research reported by (Pierce, Stacey & Barkatsas,2009), most students agreed that learning with tools is more stimulating than paper based learning which shows that they have a positive affect towards learning mathematics using tools. The authors found that male students gave a stronger positive response than female students. Their survey instrument measured affect about computers in general, whereas in the current research the survey instrument measured affect about a specific tool, which they have used for at least eight weeks. In the current research it was found that the students have positive affect about learning with ALEKS. These findings are consistent with results reported by (Pierce, Stacey & Barkatsas, 2009), but from the chosen sample, female students had stronger opinion than male students. Pierce, Stacey & Barkatsas (2009) claim that students' attitudes or perceptions can change as they are built on their experiences. This explains why female students felt more strongly than male students in the current research. After using ALEKS for minimum eight weeks, students had experienced the positive impact of ALEKS.

A learning tool, such as ALEKS, promotes understanding of mathematics, but its use proves more effective when a student is actively engaged in learning. Engaged learning will take place when students develop habits of organizing their learning tasks as well as their mental routines. Solving problems step by step on paper and taking notes during class activities are found to form routines of systematic study habits. Organizing learning tasks in the correct sequence and reading an explanation before solving the given problem are found to be habits of using ALEKS in a systematic manner.

These habits promote student's engagement in learning and consequently facilitates learning. Whereas ability to master most of the topics attempted persistently is an indicator of students' actual learning efforts and ability to learn independently, which can be easily measured with the help of ALEKS data logs. After analyzing of data logs recorded by ALEKS, it has been found that the variable *mtop* is an indicator of student's efforts as well as a predictor of their success in the course assessments. Teachers can monitor students learning progress periodically, with the help of these ALEKS data logs. Students who are not able to master at least 60% of the topics attempted may be at risk of failing and may need extra support. This finding is an extension of results established in (Dani,2015). The preliminary results reported in Dani (2015) and Dani and Nasser (2016) are derived by analyzing ALEKS log data but the curriculum context was slightly different for that research. Foundation mathematics courses were offered over 16 weeks and data logs used for analysis included details about English course marks and weekly learning progress. Dani (2015) established that students who studied regularly, were able to master 80% of the topics they attempted to master. Those students exhibited self-regulatory study habits, such as setting their own learning goals and making efforts to attain those goals. Results in the current research were not conclusive about predicting their self-regulatory study habits from ALEKS data, but those were measured from the survey items. There are three important study habits measured from the survey instrument, habits of studying systematically, habits of using ALEKS systematically and habits of seeking external help.

The findings from analysis of ALEKS data are slightly different than findings reported in (Tempelaar, Rienties, & Giesbers, 2011). In their research they measured student's efforts from their interaction with Blackboard. In the current curriculum framework, student's learning activites are centered around ALEKS, therefore the indicator detected from the analysis of ALEKS data logs is a more robust indicator of student's efforts.

The basic philosophy of mobile learning theory suggests that learning opportunities can be provided to students which will allow them to learn anytime, anywhere according to their own learning pace (Sharples, 2006;Wali, Oliver, & Winters, 2009). It was revealed that students refer to their study notes, read explanation provided by ALEKS as well as use other resources provided by teachers inside and outside their regular class. Teaching mathematics with the help of an intelligent tutor fits well within the framework of mobile learning.

Activity theory framework suggests that not just the tool but interactions with peers and other resources, such as study notes and other online resources helps the subject attain the learning goal (Engeström, 2001). The survey instrument measured the frequency of students' interactions with the tool and other resources. After analyzing these interactions, it was found that systematic study habits as mentioned above and systematic use of the tool have positive effects on the association between the subject (student) and the object (goal). These finding conform to the principles of Activity theory.

Direct and indirect associations among various factors and study habits were examined by performing path analysis. A complete summary of all hypotheses and the interpretation of their conclusions are given below.

Table 5.1: Summary of hypotheses, their conclusion and interpretation

No	Null hypothesis	Conclusion about the null hypothesis	Interpretation of conclusion
H1	Students' perceptions about *tutoring effect of ALEKS* have no impact on students' perceptions	Reject	Students' perceptions about tutoring effect of ALEKS have a positive impact on students' perceptions about cognitive effect of ALEKS.

	about *cognitive effect of ALEKS.*		
H2	There is no impact of perceptions about *tutoring effect* of ALEKS on *coursework marks.*	Reject	Students' with positive perceptions about tutoring effect of ALEKS score higher in the coursework.
H3	Systematic study habits do not change the effect of *systematic use of tools* on the perceived *tutoring effect of ALEKS.*	Reject	Those who follow Systematic study habits and systematic use of tools perceive ALEKS as a more effective tutor than those who only use the tool systematically.
H4	Systematic study habits do not change the effect of *systematic use of tools* on the perceived *cognitive effect* of ALEKS.	Reject	Those who follow Systematic study habits and systematic use of tools agree more to the fact that ALEKS develops their understanding than those who only use the tool systematically.
H5	Perceptions about tutoring effect of ALEKS do not change the impact of *systematic study habits* on the *cognitive effect*.	Reject	Those with positive perceptions about tutoring effect of ALEKS and following systematic study habits more often agree more to the fact that ALEKS develops their understanding than those who only follow systematics study habits.
H6	Students' efforts have no impact on student's final marks	Reject	Students who exert more efforts by mastering most topics score higher in the final exam than other students.

H7	Perceptions and study habits of students with different learning profiles are similar.	Retain	Students perceptions and study habits are same irrespective of their learning profiles on ALEKS
H8	Study habits of male and female students do not differ significantly.	Reject	Habits of systematics study and habits of systematic use of ALEKS are not same for male and female students. But their habits of seeking external help, level of persistence and habit of getting distracted are same.
H9	Perceptions about ALEKS are same for male and female students.	Reject	Male and female students have different perceptions about tutoring effect of ALEKS and its impact on their interest in mathematics. But their beliefs about learning with tools, perceptions about use of tools in general as well as cognitive effect of ALEKS are same.
H10	Students in all three different courses use ALEKS in the same way.	Retain	Students patterns of using ALEKS does not change according to the duration of using ALEKS.
H11	Students in three different courses have the same perceptions about ALEKS.	Reject	Students beliefs about how to learn mathematics using tools are different for students in three different courses. But perceptions about ease of use of ALEKS, its tutoring and cognitive effect as well as perceptions about learning with tools in general are same for students in all courses.

Results of testing these hypotheses imply that learning is facilitated by meaningful interactions of the subject with the tool as well as with peers and other resources in the learning environment, as proposed by the Activity Theory framework. This confirms that attempt to analyze learning activities of a large sample, based on the Activity Theory framework, is giving expected and consistent results.

During the analysis only composite factor scores were considered and their results are presented in chapter 4. But a closer look at some of the individual constituent items revealed some hidden facts about their epistemological views about learning with tools. In addition to those findings, cross-tabular frequency distribution of some of the items and gender revealed some interesting patterns. Some of the interesting patterns are discussed next.

One of the survey item sought student's agreement about the following statement: *I can solve the problem using ALEKS even though I don't understand the theory*. This item was designed with the aim of examining if they believe that conceptual understanding is necessary for problem solving. A cross tabular analysis revealed the following percentages.

Table 5.2: Perceptions of male and female students about conceptual understanding

	Female	male
Strongly agree	20.6%	12.3%
Agree	51.5%	41.5%
Neutral	22.8%	24.6%
Disagree	4.4%	9.2%
Strongly disagree	0.7%	12.3%

It can be seen from the table 5.2 that approximately 72% girls believe that they can solve problems without understanding it conceptually whereas only 54% boys agree to this view.

The percentages of both male and female students who are neutral about this are approximately equal. 22% boys do not believe that they can solve problems without understanding, which is a very affirmative view. But alarmingly this percent is much lower. It needs to be investigated if there are certain topics that they feel can be solved mechanically. This could probably be a direction for future research.

Another item was asked as follows: *ALEKS taught me how to solve real life problems using mathematics.*

It was found that 30% female and 21% male students disagreed with this statement and 33% female and 37% male students were neutral about this indicating that very few students felt that ALEKS was instrumental in teaching them how to solve real life problems. A detail investigation of course content was done to determine a possible reason behind this disagreement.

In the current curriculum of foundation mathematics, there are some topics, which are designed to provide real life example. For example, in M020 course students are expected to solve a problem of finding quantities of one of the two ingredients of a mixture, using the concepts of proportions.

> *A certain drug is made from only two ingredients: compound A and compound B. There are 5 milliliters of compound A used for every 6 milliliters of compound B. If a chemist wants to make 792 milliliters of the drug, how many milliliters of compound A are needed?*

Such problems start from a real life situation, but that situation is not experienced by the students in the current population. Consequently, it is not a meaningful problem situation for these students. This shows a mismatch between the context given in the problem statement and student's everyday life experience. Probably, such types of problems are solved by students procedurally without actually understanding the concepts behind its solution.

Another example of a mismatch appears in the context of currency and geographic references. Designing contextualized problem scenarios can eliminate the mismatch between the problem statements and student's everyday experience.

It was important to assess what percentage of students are ready and confident to learn in absence to teacher's support. Students were asked the following question*: I am not as confident in solving mathematics problem at home as I am in the classroom.*

It was found that 36% female and 35% male students think that they are not confident at home. Whereas 46% female and 48% students disagreed with the statement, which means they think they are confident. This percentage of students who are confident is slightly higher than those who are not. Considering the percentage of students who are neutral leads us to conclude that a very small percentage of students think that they are confident at home. This lack of confidence can be attributed to the fact that they have just graduated from the high school. As mentioned in the chapter 2, the foundation year is the transition year for getting ready for University. The course content and assessments should be modified so as to give them opportunity to gain the confidence of becoming independent learners.

In response to the item: *All calculations should be done on a calculator or by using an app,* 70% students either agree or strongly agree. Only 9% disagree while remaining 21% were neutral. The high percent of students might be an indication of their over dependence on the technology.

The difference between male and female students' ability to cope with failure were examined from the item: *I give up when I fail to master a topic on my own.* There was no statistical evidence to establish the difference, but cross-tabulation analysis revealed that 35% female and 33% male students declined that they give up. But 30% female and 22% male students admitted that they very often give up when they fail to master a topic. There is a need for providing motivation to the majority of students.

Thus a detail analysis revealed that there some study habits and perceptions which could probably be a cause of concern in the development of their mathematical thinking.

5.3 Analysis of research question 3

Research question 3 is restated here: Since the introduction of the iPad initiative, up to what extent are iPads being used for teaching mathematics in universities in the UAE?

From the analysis of teachers' data, it is found that teachers are actively using iPads for administrative as well as for teaching tasks. They are well aware of limitations and benefits of using iPads in teaching mathematics. Teachers believe that from the given list of six topics included in the three courses, most of the topics can be taught by embedding a small component of technology based instructions in their traditional teaching method. They are still not willing to teach these topics solely with digital tools. This belief is reflected in their actual use of tools, where the tool is either used to *support* or to *extend* learning. At the same time, it is found that the teachers have assigned a high rank to two features of tool based teaching which can *transform* learning. Those two features are *use of digital tools to provide visualization* and *develop problem solving strategies*. Though the teachers prefer to embed these features in their teaching, they are not able to do so frequently. This limited use can be attributed to the time constraints on the delivery of the course as well as the design of curriculum. In the current curriculum, all formative as well as summative assessments are written examinations conducted on ALEKS. Within a short cycle of six to eight weeks, there is a little scope for teachers to transform learning with digital tools and at the same time meet the learning objectives set out in the curriculum.

This gap between their intended use and actual use can be minimized if some interactive websites or applets are embedded within ALEKS, making it an integrated system.

5.4 Analysis of research question 4

Research question 4 is restated here: What types of interactions occur in the classroom where iPads are used for teaching mathematics?

From the data collected from class observations, it was found that the level of students' engagement in class activities is higher when interactive and personalized tools are used in teaching. These findings are consistent with the findings reported by Trouche and Drijvers (2010).

It was observed that the teachers adopted tools in their teaching only to support or to extend their learning. Though the teachers could have taught the same topics without using any digital tool, the use of tools allowed them to increase students' engagement as well as it allowed them to develop more meaningful resources which were available to students anytime, anywhere.

In addition to the resources provided by ALEKS, these multi-media resources developed by teachers provide more meaningful context.

It was noticed that some teachers preferred to integrate digital tools other than ALEKS to implement collaborative learning as well as to demonstrate visual representations, while some teachers preferred to use the traditional method of teaching without use of any digital tools other than presentation tools. The choices were found appropriate for student's course levels as well as aptitude towards mathematics. Using collaborative teaching and other interactive digital tools to foster motivation is necessary in M010 classes as the students' English language proficiency as well as aptitude and ability to understand formal language of mathematics is low at this level. Though in M030 class, students appeared less motivated and passive they were capable of understanding abstract concepts without visual demonstration. These two contrasting scenarios indicate that extent of use of digital tool can be determined based on the topic as well as the students' academic level.

In all four observations, it was noticed that teachers did not integrate ALEKS in their teaching. They used the problems from the ALEKS repository and designed their teaching strategy around those problems. This is due to the limitations of ALEKS as noted in the section 5.1. The teachers had to do so with the aim of preparing students for the summative assessments and also due to time constraint. One of the alternative strategy to motivate students could be adapting flipped teaching style (Bryson, 2016).

It was observed that learning environements in the pilot class and the Class-2 were modelled as a student-centered environement. Schoenfeld, (1992) recommends that students should solve different types of mathematical problems persistently and over a longer period, which can teach them how to think mathematically. It is further recommended in Schoenfeld, (1992) that a well-designed and well-administered problem solving activity can foster development of ability and confidence of solving problem as well as metacognition. The teachers in the pilot class and in class-2 observation demonstrated a well-designed and well-administered activity. In particular, the teacher in the pilot class also asked students to reflect on their strategy, which was not observed in other three classes. However, it can be concluded that all three teachers were conversant with different and effective methods of teaching.

According to the semiotic theory, semiotic tools which facilitate understanding of mathematical meaning through student's interactions with both worlds, the real world and the mathematical world represented by symbolic expressions. The comparison of tools used in the pilot class and Class-1 and Class-2 revealed that the interactive applet used in Class-2 was effective in unfolding the meaning associated with terms such as *vertex* as well as it was successful in keeping students engaged in the assigned mathematical activity. A tool is said to have good semiotic potential if it can unfold the meaning and engage students in the activity (Swidan, & Yerushalmy, 2016). Reflecting upon principles of theory of semiotic mediation, it can be stated that findings revealed from observation data were consistent with the theory of semiotic mediation.

It is also important to reflect upon the Activity Theory for analysis of observation data. The design implications provided by (Barab, Evans & Baek, 2004) are as follows. The instructor should play a role of facilitator and encourage students to participate. Activities should be collaborative to be more meaningful and engaging. A wide variety of tools must be incorporated. Complexity of tasks in the activity should evolve gradually where students get scaffolding and feedback. The teacher of the pilot class met all of these expectations, and that activity was found to be well-designed and provided meaningful learning experience.

The Class-2 teacher met most of the objectives, except that the teacher did not use a variety of tools. The Class-3 teacher did not implement collaboration, as a result, it was observed that students were not able to retain their interest for the complete duration of the class. Probably, teachers in the chosen institute may need professional development as well as curricular support in designing student centered learning activities.

5.5 Recommendations

As discussed above, study habits, which facilitate learning with the tool can be developed in students through guidance and periodic monitoring followed by formative feedback. Also changes in the curriculum and in the design of interface of ALEKS can be useful to develop these habits. In this section all these recommendations are given in detail.

5.5.1 Periodic monitoring of students' progress

Real time monitoring of students' persistence and actual efforts has become easy for teachers due to the use of intelligent tutor. Techniques of learning analytics can be applied to extract learning patterns and indicators of student's progress as well as their learning efforts.

As the results of analysis of ALEKS data logs indicate that not just the time spent on ALEKS, but the percent of number of topics mastered is an indicator of student's learning efforts. Students should be encouraged to master each topic that they attempt to master without giving it up. One of the possible hurdle is students' English language proficiency. It is reported in (Dani & Nasser, 2016) that there is a correlation between English language proficiency and ability to learn independently. Mobile learning can help students to overcome this barrier as they can seek help from search engines to develop their mathematics and general vocabulary.

Students who are not spending enough time or not able to master at least 70% of the topics they attempt to master, can be considered as *at risk* students. Additional support as well as motivation to study must be provided to these students.

New generation of students entering into post-secondary education are assumed to be more comfortable with technology. But it is not reasonable to assume that students' excessive use of Internet technology for social purposes make them proficient users of other types of digital tools (Bates, Bates & Sangra, 2011, pg 16). This points to the fact that though students find ALEKS easy to use, their use of ALEKS is only for mastering the content. ALEKS provides student's individual learning log graphically on the dashboard of their account. All of the students may not know how to use ALEKS data to monitor their own learning.

Teachers can include periodic orientation sessions to teach students how to check and interpret graphical information available on their ALEKS dashboard to improve their pace and quality of learning. Teachers can set weekly goals for students or encourage them to set their own goals and reward those who achieve these weekly goals to motivate them. Developing student's ability to set goals and monitor their own progress will lead to student-centered learning where students take responsibility of their own learning.

5.5.2 Improved pedagogy

It is expected that students at post-secondary level develop critical thinking so that they can assess the nature of any problem they encounter, whether the problem is well-structured or ill-structured. Then they can design appropriate problem solving strategies. Any digital tool must not be used as the goal of learning, but it must be used as a means to achieve mathematical competencies. As Hegedus et al (2017) suggest, use of a digital tool as a means to achieve mathematical competencies will be meaningful only when students are encouraged to reflect on learning as well as be critical about the solutions provided by the tool. When they develop this ability they will be in a position to use the tool as their partner or extension of themselves. (Geiger, 2005).

In the current curriculum, this part is somewhat overlooked as all formative and summative assessments are ALEKS-based tests. They don’t have to show the intermediate steps of their solution in these tests. ALEKS only provides feedback on the final answer and students are not expected to show step-by step solution. From the survey responses, it is evident that currently students are not willing to adapt systematic, reflective practices of problem solving. 53% students responded that they think *it is not necessary to solve a problem step by step on paper when you can use some app on iPad for problem solving.* It is recommended that teachers include teaching strategies, such as group work, peer support in which students will help other students in problem solving. Those students who provide support to their peers, get an opportunity to reflect on and explain their thinking.

But such teaching strategies may not develop desired reflective practices in all students. Changing assessment strategy is another possible method to ensure that students use any tools consciously and they are able to understand and explain their problem solving strategy as well as justify their solution.

Though metacognition strategies are not included in the software, it can be achieved by including external assessments, such as, mini-projects. This will also ensure deep learning.

It is possible for teachers and students to access the solution to homework assessments and quizzes but they cannot access those in the progress tests. Teachers can set frequent and periodic homework tasks and provide detail feedback on their solution which is not provided by the software. Student's learning log reveals how much time the student has spent on each problem and how many times student needed to read the explanation. Teachers can see the student's learning logs to identify students who are struggling to learn by reading the explanation provided by ALEKS.

Thus a new model of pedagogy to teach using an intelligent tutor now involves teaching of mathematics as well as teaching how to use the tool. Skills of solving mathematics problems and skills of using all features of ALEKS may evolve simultaneously as suggested by (Heid, 2005). Apart from this modification in pedagogy, some more modifications pertaining to curriculum are suggested next.

5.5.3 Changes in curriculum

In the UAE, the Emirates of Dubai alone has 153 private schools offering 15 different curricula (KHDA School Census 2012/13 as reported in Gistaki and Roby, 2015). Students entering into foundation program of any university in the UAE come from different high school curricula. They may have varying levels of computational skills in different mathematics subject areas. It may be possible that all students may not have mastered all prerequisite knowledge required for joining any degree program. One of the objectives of a coherent curriculum is to assist all students to achieve significant cognitive growth irrespective of their previously achieved mastery of skills. Instructions should be guided by designs in such a way that it allows students to participate in intellectually stimulating activities (Anon, 1999).

A traditional higher education mathematics curriculum follows the linear progression design, of skills and procedures, in which it is expected that students need to master all previous skills and procedures before moving on to the next skill. For example, skills of factoring and simplifying algebraic expression is a prerequisite knowledge for mastering the skills solving quadratic equations. The main activity in this case is learning how to solve quadratic equations but it cannot be mastered without following the steps of algebraic factoring. Underachieving students may have to struggle a lot and spend more time in factoring and simplifying expressions than their peers. Consequently, they may lose interest before starting the main activity of solving quadratic equations.

The curriculum should provide support for use of digital tools to carry out mechanical and repetitive activities, such as factoring and simplification. With the help of mathematical apps provided on iPads, it is possible for students to master these skills of mathematics in their own pace. iPad based apps allow students with all levels of mathematical ability to solve problems which may motivate them to participate in the whole class learning activity. A mathematics curriculum can be enriched by designing units that evolve to increasing levels of rigor and student engagement by designing iPad based activities.

ALEKS provides a feature for monitoring progress within a specific time period. Using this feature, it is possible to set assignments in which points are awarded for completing tasks set by the teacher within given time period. For example, teacher can set a goal of adding 30 points on ALEKS in one week's time. ALEKS can award points in proportion to the number of points added in that week. Students who add 30 points get 100% whereas students who add 15 points only are awarded 50%. These assignments can be included as summative assessments. Such assessments will serve dual purpose, first student will master topics as per a standard pace and second it will force students to study regularly.

In addition to this, one or two formative quizzes can be set in which student's written steps will be graded and not just the final answer on ALEKS. More sophisticated project-based assessments may be set to allow students to explore, model real life problems and think for themselves. A new curriculum can be designed in which students will be encouraged to explore ideas. A learning environment can be developed in which students will get opportunities to experiment and explore so that they can relate mathematics learnt in class with other subjects as well as their everyday experiences. Assessments can be designed in which they are encouraged to think about all possible strategies and solutions.

Mathematics curriculum at the university level often emphasize on the importance of promoting depth of knowledge rather than shallow coverage of many topics (Shield, & Dole 2013). In order to develop deep knowledge, variety of assessments can be set. Rather than using only one type of technology, an appropriate mix of various technologies must be used for formative assessments. As mentioned in (Dede, 2008), simple drill exercises based on behaviorist approach are appropriate for mastering the skills. In order to test students' cognitive development, intelligent tutoring systems can be used for assessment. Software providing different real life scenarios through simulation can be used for fostering constructivist learning. These simulation-based tasks can be used in setting group projects allowing students enough time for experimenting and constructing their own knowledge.

During investigation of the third and fourth research questions, it was found that ALEKS is mainly used as a tool for drill and practice. Outcome of such drill and practice techniques is improvement in students' procedural skills. It is not possible to assess if students develop conceptual understanding.

If the goal of teaching is to develop both skills and provide authentic learning experience, then either the contents of the course should be modified or the delivery and assessment strategies should be modified.

5.5.4 Professional development for teachers

As it was found from teachers' survey, most often implemented feature is mobile learning and the least often implemented feature is exploring problem solving strategies. It points towards the fact that the mobile technology is not yet implemented to its full potential as development of mathematical knowledge covers not just understanding of concepts, facts and procedural skills, but also ability to determine appropriate problem solving strategy (Jaafar, Wan, and Ahmad, 2010, Özcan, 2016). A technology integrated curriculum is needed to transform mathematics education which will emphasize on collaborative and higher-order thinking skills (Bray & Tangney,2016; Coffland, & Xie, 2015). As noted by Hegedus, & Tall (2016) teachers' professional development in integrating new tools in mathematics curriculum is a critical factor. The teachers training should not be limited to training of using a set of tools but it should also be aimed at helping them to transform their teaching practices.

5.5.5 Recommendations for ALEKS improvement

When this research was carried out, older version of ALEKS was used. Teachers and students are comfortable with the circular layout of topics as they can see all topics at a glance as opposed to a new version of ALEKS in which topics are laid out along a horizontal navigation pane. If the old interface needs to be used, then some changes are recommended in the ALEKS interface. If students attempt to keep one topic incomplete and move to the next one, a warning or hint can be displayed. Also, when students complete their progress assessment, a list of topics that they lost in the assessment should be immediately displayed on their dashboard. In the current version, teachers can see this list easily, but students cannot find it easily. This immediate feedback will be useful for students to monitor their own progress.

Educators' main interest is to get an overview of students' mastery of course content and overall progress periodically. But they normally expect to get it directly without further manipulation of log data. In most cases, techniques of learning analytics must be applied to extract hidden interactions. Results of such analysis must be presented in a manner so that teachers can interpret them easily. (Ali et al, 2013).

A visual representation of list of students who might be at risk which can be shown on the dashboard of teacher's account can give teachers more support to monitor class progress.

Considering low level of English language proficiency of students in this region, ALEKS should provide more visual explanation and support for translations.

5.6 Contribution of this research

This research investigated how digital tools are being used by teachers and students in higher education institute in the UAE. This is a first attempt to discover these findings in the context of foundation year mathematics courses, in which intelligent tutor is used for teaching and the courses are delivered on mobile devices. These findings provide insights into the ways of learning of students who are exposed to English medium of instruction as well as the use of digital tools in learning for the first time. These results can be useful for planning the future curriculum as well as educational policies.

There is a consensus among researchers and educators about the effectiveness of mobile devices in improving learning experience. Results from large scale empirical studies are required to build a broader knowledge base to understand potential benefits and drawbacks as well as how to make the best use of such devices (Gitsaki & Robby, 2015). This research adds substantial empirical evidence about suitability of mobile learning as well as identifies external factors which can influence attainment of learning ourcomes.

This research contributes to the existing research literature a survey instrument to measure perceptions, beliefs of students about using an intelligent tutor and a survey instrument for teachers which can measure the gap between their intended use and actual use of digital tools in teaching mathematics. Findings about perceptions and patterns of usage of foundation year mathematics students and teachers from the middle east region is another added contribution to the existing research literature.

In the existing research literature, it is found that the components of an activity are often analyzed qualitatively on a small sample as proposed by the activity theory framework. In an attempt to analyze the interplay among the three components on a large sample, a survey instrument was designed to measure different interactions between the subject and the tool. This instrument can provide a basis for developing similar instruments in a different context. Analysis of activities on a large sample is a novel part of this research. This is a significant contribution to the research literature. With the help of this instrument it will be possible to extend this research longitudinally.

Frameworks for mobile learning have been developed by some researchers but the focus of their research is not aimed at mathematics education (Motiwalla, 2007; Koole, 2009; Yeongeong, 2011). As Hoyles and Noss (2003) point out, “abstraction is a key concept of mathematics which is not shared by other disciplines”. Therefore, it is necessary to have a framework suitable for teaching mathematics with iPads. Results obtained from the four research questions can provide constituents of such a framework.

In their recent research (Gitsaki and Robby, 2015) reported that there is an increasing demand for graduates from Science, Technology, Engineering and Mathematics (STEM) discipline, but still comparatively fewer number of high school students are attracted towards the STEM career opportunities. Using interactive digital tools, such as ALEKS, can be one of the possible ways to make STEM courses easy and interesting. This research provides empirical evidence that student’s engagement in learning increases due to interactive tools.

Since the results of quantitative analysis are statistically significant, they can be generalized to the chosen population, which is all students and teachers from the chosen institute.

5.7 **Limitations and future research**

One limitation of this study is generalizability on a limited scale. Since a mixed-method research approach is chosen for this study, the findings from the qualitative data analysis cannot be generalized. Though the results of quantitative study are significant, they should be generalized with care. Study habits and perceptions about learning with intelligent tutor cannot be generalized to a different type of digital tool. Also as noted in (Dani & Nasser, 2016), students with higher proficiency in English language may exhibit different patterns of interaction with an intelligent tutor than those found in this empirical study.

In (Dani, 2016) more variables were extracted from ALEKS which were instrumental in determining predictors of knowledge retention. Those variables were extracted from ALEKS after the second ALEKS administered summative assessment. On a large scale, it was not possible extract those variables because of some logistic issues. In the future research, this data can be extracted for investigating more information about student's learning patterns.

Another instrument can be developed for teachers to measure their patterns of interacting with ALEKS.

This research can be further extended longitudinally to examine how these students retain their knowledge of mathematics as well as skills of using digital tools and coping up with mathematics in their degree program. This research can be further strengthened by incorporating views of curriculum designers and other policy makers which can shed some light on the rationale for including particular types of tools in the curriculum.

Another detail study about impact of linguistic abilities on the comprehension of formal mathematical language and symbolic expressions can be carried out on the same population of Arab students.

References

Aamri, A., & Suleiman, K. (2011). The Use of Mobile Phones in Learning English Language by Sultan Qaboos University Students: Practices, Attitudes and challenges. *Canadian Journal on Scientific & Industrial Research*, vol. 2(3).

Adcock, A., & Eck, R. (2005). Reliability and factor structure of the attitude toward tutoring agent scale (ATTAS). *Journal of Interactive Learning Research*, vol. *16*(2), pp. 195-205.

Ali, L., Asadi, M., Gašević, D., Jovanović, J., & Hatala, M. (2013). Factors influencing beliefs for adoption of a learning analytics tool: An empirical study. *Computers & Education*, vol. *62*, pp. 130-148.

Aleven, V., & Koedinger, K. (2002). An effective metacognitive strategy: Learning by doing and explaining with a computer-based Cognitive Tutor. *Cognitive science*, vol. *26*(2), pp. 147-179.

Ally, M. (2004). Foundations of educational theory for online learning. In T. Anderson, & F. Elloumi (Eds.), *Theory and practice of online learning* (pp. 3-31), Athabasca: Athabasca University Press.

Anderson, J., & Schunn, C. (2000). Implications of the ACT-R learning theory: No magic bullets. *Advances in instructional psychology, Educational design and cognitive science*, 1-33.

Anderson, R. (2008). Implications of the information and knowledge society for education. In *International handbook of information technology in primary and secondary education* (pp. 5-22). New York: Springer.

Anderson, J., Boyle, C., Corbett, A., & Lewis, M.(1990). Cognitive modeling and intelligent tutoring. *Artificial intelligence*, vol. *42*(1), pp. 7-49.

Aguilar, M., & Puga, D. (2015). Mobile Help Seeking In Mathematics. *Mobile Learning and Mathematics*, 176.

Anon (1999). *Designing Mathematics or Science Curriculum Programs: A Guide for Using Mathematics and Science Education Standards*, The National Academies Press. Available at: http://www.nap.edu/openbook.php?record_id=9658.

Antonenko, P., Toy, S., & Niederhauser, D. (2012). Using cluster analysis for data mining in educational technology research. *Educational Technology Research and Development*, vol. *60*(3), pp.383-398.

Antonenko, P. (2015). The instrumental value of conceptual frameworks in educational technology research. *Educational Technology Research and Development*, vol. *63*(1), pp. 53-71.

Barab, S., Evans, M., & Baek, E. (2004). Activity theory as a lens for characterizing the participatory unit. *Handbook of research on educational communications and technology*, vol. *2*, pp. 199-213.

Balacheff, N., & Kaput, J. (2012). Computer-Based Learning Environments in Mathematics. *International Handbook of Mathematics Education*, vol (*4)*, 469-500.

Bardini, C., & Pierce, R. (2015). Assumed Mathematics Knowledge: The Challenge of Symbols. *International Journal of Innovation in Science and Mathematics Education (formerly CAL-laborate International)*, vol. *23*(1).

Bates, A., & Poole, G. (2003). *Effective Teaching with Technology in Higher Education: Foundations for Success*. Jossey-Bass, An Imprint of Wiley. 10475 Crosspoint Blvd, Indianapolis, IN 46256.

Bates, A., Bates, T., & Sangra, A. (2011). *Managing technology in higher education: Strategies for transforming teaching and learning*. John Wiley & Sons.

Batista, S., Behar, P., & Passerino, L. (2013). Activity theory and M-learning in the teaching of Calculus. *Ubiquitous and Mobile Learning in the Digital Age*, vol. 8(2), pp. 93-108.

Beal, C., Walles, R., Arroyo, I., & Woolf, B. (2007). On-line tutoring for math achievement testing: A controlled evaluation. *Journal of Interactive Online Learning*, vol. *6*(1), pp. 43-55.

Becker, H., & Anderson, R.(1998). Teaching, learning, and computing: 1998. A national survey of schools and teachers describing their best practices, teaching philosophies, and uses of technology.

Berger, M. (2010). A semiotic view of mathematical activity with a computer algebra system. *Revista latinoamericana de investigación en matemática educativa*, vol. *13*(2), pp. 159-186.

Brummelhuis, A., & Kuiper, E. (2008). Driving forces for ICT in learning. In *International handbook of information technology in primary and secondary education* (pp. 97-111). Springer US.

Belland, B. (2017). Intended Learning Outcomes and Assessment of Computer-Based Scaffolding. In *Instructional Scaffolding in STEM Education* (pp. 79-106). Springer International Publishing.

Bhattacherjee, A. (2012), Social Science Research: Principles, Methods, and Practices, Textbooks Collection. Book 3.http://scholarcommons.usf.edu/oa_textbooks/3

Bokhove, C., & Drijvers, P. (2010). Symbol sense behavior in digital activities. *For the learning of mathematics, vol. 30*(3), pp.43-49.

Bokhove, C., & Drijvers, P. (2012). Effects of a digital intervention on the development of algebraic expertise. *Computers & Education*, vol. *58*(1), pp. 197-208.

Bonk, C., & Cunningham, D. (1998). Searching for learner-centered, constructivist, and sociocultural components of collaborative educational learning tools. *Electronic collaborators: Learner-centered technologies for literacy, apprenticeship, and discourse*, pp. 25-50.

Bray, A., & Tangney, B. (2016). Enhancing student engagement through the affordances of mobile technology: a 21st century learning perspective on Realistic Mathematics Education. *Mathematics Education Research Journal*, vol. *28*(1), pp. 173-197.

Bussi, M. B., & Mariotti, M. A. (2008). Semiotic mediation in the mathematics classroom: Artifacts and signs after a Vygotskian perspective. *Handbook of international research in mathematics education, New York*, pp. 746-783.

Bryson, C. (2016). Engagement through partnership: Students as partners in learning and teaching in higher education.

Cangelosi, R., Madrid, S., Cooper, S., Olson, J., & Hartter, B. (2013). The negative sign and exponential expressions: Unveiling students' persistent errors and misconceptions. *The Journal of Mathematical Behavior*, vol. *32*(1), pp. 69-82.

Cavanaugh, C, Hargis, J., Kamali T., Soto M. (2013). Substitution to augmentation: faculty adoption of iPad mobile learning in higher education, Interactive Technology and Smart Education, Vol. 10(4) pp. 270 – 284.

Cayton-Hodges, G., Feng, G., & Pan, X. (2015). Tablet-Based Math Assessment: What Can We Learn from Math Apps?. *Journal of Educational Technology & Society*, vol. *18*(2), pp. 3-20.

Chappuis, J. (2014). Seven strategies of assessment for learning.2nd ed. Pearson.

Chen, T., Yunus, M., Ali, W., & Bakar, A. (2008). The Effect of an Intelligent Tutoring System (ITS) on Student Achievement in Algebraic Expression. *Online Submission*, vol. *1*(2), pp. 25-38.

Chen, T, Yunus, M., Suraya, A., Ali, W., & Bakar, A. (2008). The Effect of an Intelligent Tutoring System (ITS) on Student Achievement in Algebraic Expression. Online Submission, vol. 1(2), pp-25-38.

Chi, M., Bassok, M., Lewis, M., Reimann, P., & Glaser, R. (1989). Self-explanations: how students study and use examples in learning to solve problems. Cognitive Science, vol. 13, pp. 145-182.

Chiu, Y., Liang, J., & Tsai, C. (2013). Internet-specific epistemic beliefs and self-regulated learning in online academic information searching. *Metacognition and learning*, *Vol* (3), pp. 235-260.

Cobb, P. (1994). Where is the mind? Constructivist and sociocultural perspectives on mathematical development. *Educational researcher*, vol. *23*(7), pp. 13-20.

Cobb, P., Yackel, E., & Wood, T. (1992). A constructivist alternative to the representational view of mind in mathematics education. *Journal for Research in Mathematics education*, pp. 2-33.

Cochrane, T. D. (2014). Critical success factors for transforming pedagogy with mobile Web 2.0. *British Journal of Educational Technology*, vol. *45*(1), pp. 65-82.

Coffland, D., & Xie, Y. (2015). The 21st Century Mathematics Curriculum: A Technology Enhanced Experience. In *Emerging Technologies for STEAM Education*, Springer International Publishing, pp. 311-329.

Cohen, L., Manion, L., & Morrison, K. (2013). *Research methods in education*. Routledge.

Cook, D., Gelula, M., Dupras, D., & Schwartz, A. (2007). Instructional methods and cognitive and learning styles in web-based learning: report of two randomised trials. *Medical education*, vol. *41*(9), pp. 897-905.

Creswell, J. (2008). Educational research: Planning, conducting and evaluating quantitative and qualitative research (3rd Ed.). New Jersey, USA: Pearson Education Inc.

Dani, A. (2015). Mining Data-Logs from Intelligent Tutor to Create Learning Profiles of Students, International Conference on Innovative Engineering and Technologies, CAASR-ICIET`15, Bangkok, pp. 101-113.

Dani, A. (2016). Students' patterns of interaction with a mathematics intelligent tutor: Learning analytics application. International Journal on Integrating Technology in Education (IJITE) Vol.5(2), June 2016

Dani, A., & Nasser, R. (2016). Use of Intelligent Tutor in Post-Secondary Mathematics Education in the United Arab Emirates. *TOJET*, vol. *15*(4) pp. 152-162.

Dede, C. (2008). Theoretical perspectives influencing the use of information technology in teaching and learning. In *International handbook of information technology in primary and secondary education* (pp. 43-62). Springer US.

Desmarais, M., & Baker, R. (2012). A review of recent advances in learner and skill modeling in intelligent learning environments. *User Modeling and User-Adapted Interaction*, vol. *22*(1-2), pp. 9-38.

Drijvers, P., Doorman, M., Boon, P., Reed, H., & Gravemeijer, K. (2010). The teacher and the tool: Instrumental orchestrations in the technology-rich mathematics classroom. *Educational Studies in Mathematics*, vol. 75(2), pp. 213-234.

Drijvers, P., Godino, J. D., Font, V., & Trouche, L. (2013). One episode, two lenses. *Educational Studies in Mathematics*, vol. 82(1), pp.23-49.

Dunleavy, M., Dede, C., & Mitchell, R. (2009). Affordances and limitations of immersive participatory augmented reality simulations for teaching and learning. *Journal of Science Education and Technology, vol.* 18(1), pp. 7-22.

Erbas, A. K., Ince, M., & Kaya, S. (2015). Learning Mathematics with Interactive Whiteboards and Computer-Based Graphing Utility. *Journal of Educational Technology & Society, vol.* 18(2), pp. 299-312.

Ertmer, P., & Newby, T. (1993). Behaviorism, Cognitivism, Constructivism: Comparing critical features from instructional design perspective. *Performance improvement quarterly*, vol. 6(4), pp. 50-72

Engeström, Y. (2001). Expansive learning at work: Toward an activity theoretical reconceptualization. *Journal of education and work*, vol. *14*(1), pp. 133-156.

Falmagne, J., Cosyn, E., Doignon, J., & Thiéry, N. (2006). The assessment of knowledge, in theory and in practice. In *Formal concept analysis* (pp. 61-79). Springer: Berlin Heidelberg.

Fensom, J. (2011). Teaching International Baccalaureate Mathematics with Technology. In A. Oldknow, & C. Knight (Eds.), Mathematics education with digital technology (pp. 205-212). London: Continuum International Publishing Group.

Field, A. (2009). *Discovering statistics using SPSS*. Sage publications.

Fisher, B., Lucas, T., & Galstyan, A. (2013). The role of iPads in constructing collaborative learning spaces. *Technology, Knowledge and Learning*, vol. *18*(3), pp. 165-178.

Geiger, V. (2005). Master, servant, partner and extension of self: A finer grained view of this taxonomy. A finer grained view of this taxonomy. In J.P. Clarkson, A. Downton, D. Gronn, M. Horne, A. McDonough, R. Pierce, & A. Roche (Eds.), *Building connections: Research, theory and practice.* (Proceedings of the 28th annual conference of the Mathematics Education Research Group of Australasia, Melbourne, pp. 369-376. Melbourne: MERGA.

Georgia L.and Symeon R. (2010). Using computer supported collaborative learning strategies for helping students acquire self-regulated problem-solving skills in mathematics, Computers & Education, *vol* 54(1), pp 3-13.

Gitsaki, C., Robby, M., Priest, T., & Hamdan, K. (2013). A research agenda for the UAE iPad Initiative. Learning and Teaching in Higher Education: Gulf Perspectives, vol. 10(2).

Gitsaki, C., & Robby, M. A. (2015). Evaluating mobile technology in math education: A case study. In H. Crompton & J. Traxler (Eds.). Mobile learning and STEM: Case studies in practice (pp. 29-42). Oxford, UK: Routledge.

Glesne, C. (2011). *Becoming qualitative researchers-An introduction* (4th ed.). Boston, MA: Pearson Education.

Goldin, G. (2002). Affect, meta-affect, and mathematical belief structures. In *Beliefs: A hidden variable in mathematics education?* (pp. 59-72). Springer Netherlands.

Goos, M., Galbraith, P., Renshaw, P., & Geiger, V. (2000). Reshaping teacher and student roles in technology-enriched classrooms. *Mathematics Education Research Journal*, vol. 12(3), pp. 303-320.

Greller, W., & Drachsler, H. (2012). Translating learning into numbers: A generic framework for learning analytics. *Educational technology & society*, vol. *15*(3), pp.42-57.

Greenes, C. (1995). Mathematics learning and knowing: A cognitive process. *Journal of Education*, pp. 85-106. Hagerty, G., & Smith, S. (2005). Using the Web-based interactive software ALEKS to enhance college algebra. *Mathematics & Computer Education*, vol. *39*(3), pp. 183-194.

Hannafin, M. & Land, S. (1997). The foundations and assumptions of technology-enhanced student-centered learning environments. *Instructional science*, vol. *25*(3), pp. 167-202.

Hannula, M. (2012). Exploring new dimensions of mathematics-related affect: embodied and social theories. *Research in Mathematics Education*, *vol. 14*(2), pp.137-161.

Handal, B., MacNish, J., & Petocz, P. (2013). Adopting Mobile Learning in Tertiary Environments: Instructional, Curricular and Organizational Matters. *Education Sciences*, vol. 3(4), pp.359-374.

Hargis, J., Cavanaugh, C., Kamali, T., & Soto, M. (2014). A federal higher education iPad mobile learning initiative: triangulation of data to determine early effectiveness. *Innovative Higher Education*, vol. *39*(1), pp. 45-57.

Hauk, S., & Segalla, A. (2005). Student perceptions of the web-based homework program WeBWorK in moderate enrollment college algebra classes. *The Journal of Computers in Mathematics and Science Teaching*, vol. *24*(3), pp. 229-261.

Hegedus, S., & Tall, D. (2016). Foundations for the future: The potential of multimodal technologies for learning mathematics. *Handbook of international research in mathematics education*, pp. 543-562.

Hegedus, S., Laborde, C., Brady, C., Dalton, S., Siller, H. S., Tabach, M., Trgalova J. & Moreno-Armella, L. (2017). Uses of Technology in Upper Secondary Mathematics Education. In *Uses of Technology in Upper Secondary Mathematics Education* (pp. 1-36). Springer International Publishing.

Henderson, M., Selwyn, N., & Aston, R. (2015). What works and why? Student perceptions of ‘useful’ digital technology in university teaching and learning. *Studies in Higher Education*, pp. 1-13.

Heid, M. K. (2005). Technology in mathematics education: Tapping into visions of the future. In W.J. Masalski & P.C, Elliott (Eds.) Technology-supported mathematics learning environments, (pp. 345-366). Reston, VA: NCTM.

Hitt, F., & Kieran, C. (2009). Constructing knowledge via a peer interaction in a CAS environment with tasks designed from a task–technique–theory perspective. *International Journal of Computers for Mathematical Learning*, vol. *14*(2), pp. 121-152.

Hoyles, C., & Noss, R. (2003). What can digital technologies take from and bring to research in mathematics education? (A. Bishop, M. Clements, C. Keitel, J. Kilpatrick, & F. Leung, Eds.) *Second international handbook of mathematics education*, vol. 1, (pp. 323-349). Netherlands: Springer.

Hoyles, C., Noss, R., & Kent, P. (2004). On the integration of digital technologies into mathematics classroom. *International journal of computers for Mathematical learning*, vol. 9(3), pp. 309-326.

Jaafar, Wan M., and Ahmad F. (2010). "Mathematics self-efficacy and meta-cognition among university students." *Procedia-Social and Behavioral Sciences* vol. 8, pp. 519-524.

Jackson, G., Graesser, A., & McNamara, D. (2009). What Students Expect May Have More Impact Than What They Know or Feel. In AIED, pp. 73-80.

Jansen, A., DiNapoli, J., & McKenney, K. (2017). Reconsidering Affect in Mathematics Education. *Journal for Research in Mathematics Education*, vol. *48*(1), pp. 106-110.

Jonassen, D. (2000). Revisiting activity theory as a framework for designing student-centered learning environments. In D. Jonassen, & S. Land (Eds.), *Theoretical foundations of learning environments* (pp. 89-121). New Jersey, United States of America: Lawrence Erlbaum Associates Inc.

Jonassen, D. (2003). Using cognitive tools to represent problems. *Journal of research on Technology in Education*, vol. *35*(3), pp. 362-381.

Johnson, J., & Walker, M. (2011). Trigonometry students' knowing when to use hand-held CAS technology to make sense of mathematics. *Journal of Mathematical Sciences and Mathematics Education*, vol. *6*(2), pp. 17-33.

Kaino, L. (2008). Technology in learning: Narrowing the gender gap. *Eurasia Journal of mathematics, science and Technology Education*, vol. *4*(3), pp. 263-268.

Kao, M. & Lehman, J. (1997) Scaffolding in a computer-based constructivist environment for teaching statistics to college learners. Paper presented at the 1997 Annual Meeting of American Educational Research Association, Chicago, IL. (ERIC Document Reproduction Service No. ED 408317).

Kaptelinin, V. (1996). Computer-mediated activity: Functional organs in social and developmental contexts. *Context and consciousness: Activity theory and human-computer interaction*, pp. 45-68.

Karagiorgi, Y., & Symeou, L. (2005). Translating Constructivism into Instructional Design: Potential and Limitations. Educational Technology & Society, *vol*. 8(1), pp. 17-27.

Kawulich, B. (2005). Participant Observation as a Data Collection Method. *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research* [Online Journal], *Vol 6*(2). Retrieved from

http://www.qualitative-research.net/index.php/fqs/article/view/466/996

Ke, F., & Hsu, Y. (2015). Mobile augmented-reality artifact creation as a component of mobile computer-supported collaborative learning. *The Internet and Higher Education*, *26*, 33-41.

Kearneya, M., Schucka, S., & Burdenb, K. P. (2012). Viewing mobile learning from a pedagogical perspective. *Research in Learning Technology*, vol. 20(11406).

Kemp, A. (2011). Why use technology to teach mathematics? In A. Oldknow, & C. Knight (Eds.), *Mathematics education with digital technology* (pp. 212-219). London: Continuum International Publishing Group.

Kieran, C., & Drijvers, P. (2006). The co-emergence of machine techniques, paper-and-pencil techniques, and theoretical reflection: A study of CAS use in secondary school algebra. *International journal of computers for mathematical learning*, vol. *11*(2), pp. 205-263.

Kieran, C., & Saldanha, L. (2008). Designing tasks for the co-development of conceptual and technical knowledge in CAS activity: An example from factoring. *Research on technology and the teaching and learning of mathematics*, vol. *2*, pp. 393-414.

Koole, M. (2009). A model for framing mobile learning. *Mobile learning: Transforming the delivery of education and training*, *vol. 1*(2), pp. 25-47.

Kotsiantis, S., Tselios, N., Filippidi, A. & Komis, V. (2013). Using learning analytics to identify successful learners in a blended learning course. *International Journal of Technology Enhanced Learning*, vol. *5*(2), pp. 133-150.

Kutti, K. (1995). Activity theory as a potential framework for human-computer interaction. In B. Nardi (Ed.), Context and Consciousness: Activity Theory and Human Computer Interaction (pp. 17-44). Cambridge: MIT Press.

Lagrange, J.-b. (1999). Learning pre-calculus with complex calculators: Mediation and instrumental genesis. In O. Zaslavasky (Ed.), Proceedings of the *Conference of the International Group for Psychology of Mathematics Education*, vol. 100.

Lagrange, J. B. (2005). Curriculum, classroom practices, and tool design in the learning of functions through technology-aided experimental approaches. *International Journal of Computers for Mathematical Learning*, vol. *10*(2), pp.143-189.

Lagrange, J. B., & Minh, T. K. (2010). Learning about Functions with a Geometrical and Symbolic Software Environment: a Study of Students' Instrumental Genesis along Two Years. Asian Technology Conference in Mathematics, Kuala Lumpur.

Lapp, D. A., Ermete, M., Brackett, N., & Powell, K. (2013). Linked Representations in Algebra: Developing Symbolic Meaning. *MatheMatics teacher*, vol. *107*(4), pp.306-312.

Lavicza, Z. (2007). Factors Influencing the Integration of Computer Algebra Systems into University-Level Mathematics Education. *International Journal for Technology in Mathematics Education*, vol. 14(3).

Lavicza, Z. (2010). Integrating technology into mathematics teaching at the university level. *ZDM*, vol. 42(1), pp. 105-119.

Leigh-Lancaster, D. (2000). Curriculum and Assessment Congruence--Computer Algebra Systems (CAS) in Victoria. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.136.1466&rep=rep1&type=pdf

Libbrecht, P., Rebholz, S., Herding, D., Müller, W. &Tscheulin, F. (2012). Understanding the Learners' Actions when Using Mathematics Learning Tools. In *Intelligent Computer Mathematics* (pp. 111-126). Springer Berlin Heidelberg.

Little, T., Card, N., Bovaird, J., Preacher, K. & Crandall, C. (2007). Structural equation modeling of mediation and moderation with contextual factors. *Modeling contextual effects in longitudinal studies*, vol. *1*, pp. 207-230.

Lynch, J. (2006). Assessing effects of technology usage on mathematics learning. *Mathematics Education Research Journal*, vol. *18*(3), pp. 29-43.

Maracci, M., Cazes, C., Vandebrouck, F., & Mariotti, M. (2013). Synergies between theoretical approaches to mathematics education with technology: A case study through a cross-analysis methodology. *Educational Studies in Mathematics*, vol. *84*(3), pp. 461-485.

Mark, M., & Greer, J. (1993). Evaluation methodologies for intelligent tutoring systems. *Journal of Interactive Learning Research*, vol. *4*(2), pp. 129-142.

Maschietto , M., & Trouche, L. (2010). Mathematics learning and tools from theoretical, historical and practical points of view: the productive notion of mathematics laboratories. *ZDM*, vol. 42(1), pp. 33-47.

Mat Roni, S. (2014). Introduction to SPSS, School of Business, Edith Cowan University, Australia. Retrieved [10-May-2016] from www.researchgate.net/publication/262151892_Introduction_to_SPSS.

Maxwell, J. (2008). Designing a qualitative study. *The SAGE handbook of applied social research methods*, vol. *2*, pp. 214-253.

Mayes, R. (2001). CAS applied in a functional perspective college algebra curriculum. *Computers in the Schools*, vol. *17*(1-2), pp. 57-75.

McArthur, D., *&* Stasz, C. *(*1989*).* An intelligent tutor for basic algebra *(WD-2781-NSF).* Santa Monica, CA*: The Rand Corporation.*

McGatha, M., & Bush, W. (2013). Classroom assessment in mathematics. In J. McMillan (Ed.), *SAGE handbook of research on classroom assessment.* (pp. 448-461). Thousand Oaks, SAGE Publications, Inc.: CA

Melis, E., & Siekmann, J. (2004). Activemath: An intelligent tutoring system for mathematics. *Artificial Intelligence and Soft Computing-ICAISC 2004*, pp. 91-101.

Miller, T. (2009). Formative computer-based assessment in higher education: The effectiveness of feedback in supporting student learning. *Assessment & Evaluation in Higher Education*, vol. *34*(2), pp. 181-192.

Misfeldt, M. (2013). Instrumental Genesis in GeoGebra Based Board Game Design. In *Eighth Congress of European Research in Mathematics Education (CERME 8* (pp. 2664-2673).

Motiwalla, L. (2007). Mobile learning: A framework and evaluation. *Computers & Education*, vol. 49(3), pp. 581-596.

Mourtada, R., & Salem, F. (2010). The role of ICT in cultivating innovation: the case of the UAE. In *Proceedings of the 4th International Conference on Theory and Practice of Electronic Governance* (pp. 375-376). ACM.

Muis, K. (2004). Personal epistemology and mathematics: A critical review and synthesis of research. *Review of educational research*, vol. *74*(3), pp. 317-377.

Muijs, D. (2010). *Doing quantitative research in education with SPSS*. Sage.

Mwanza-Simwami, D. (2011). AODM as a framework and model for characterising learner experiences with technology. *Journal of e-Learning and Knowledge Society*, vol. *7*(3), pp. 75-85.

Nardi, B. A. (1996). Studying context: A comparison of activity theory, situated action models, and distributed cognition. *Context and consciousness: Activity theory and human-computer interaction*, pp. 69-102.

Nguyen, D, Hsieh, Y. & Allen, G. (2006). The impact of web-based assessment and practice on students' mathematics learning attitudes. *Journal of Computers in Mathematics and Science Teaching*, vol. *25*(3), pp. 251-279.

Nguyen, L., Barton, S., & Nguyen, L. (2014). Ipads in higher education—hype and hope. *British Journal of Educational Technology*.

Nicol, D. (2006). Increasing success in first year courses: Assessment re-design, self-regulation and learning technologies. In *Proceedings of the 23rd annual ascilite conference*.

Noss, R., & Hoyles, C. (1996). *Windows on mathematical meanings: Learning cultures and computers* (Vol. 17). Springer Science & Business Media.

Oates, G. (2011). Sustaining integrated technology in undergraduate mathematics. *International Journal of Mathematical Education in Science and Technology*, vol. *42*(6), pp. 709-721.

Olive, J. (2011). Research on Technology in Mathematics Education: Theoretical Frameworks and Practical Examples. *Presented Korea Society of Educational Studies in Mathematics Conference*. Seoul, South Korea.

Olley, C. (2011). Modelling, functions and estimation: A pizza problem. In A. Oldknow, & C. Knights (Eds.), *Mathematics Education with digital technology* (pp. 163-173). London: Continuum International Publishing Group.

Ozdamar, K., & Metcalf, D. (2011). The current perspectives, theories and practices of mobile learning. TOJET: The Turkish Online Journal of Educational Technology, vol. 10(2).

Özcan, Z. (2016). The relationship between mathematical problem-solving skills and self-regulated learning through homework behaviours, motivation, and metacognition. *International Journal of Mathematical Education in Science and Technology*, vol. *47*(3), pp. 408-420.

Palinkas, L., Horwitz, S., Green, C., Wisdom, J., Duan, N., & Hoagwood, K. (2015). Purposeful sampling for qualitative data collection and analysis in mixed method implementation research. *Administration and Policy in Mental Health and Mental Health Services Research*, vol. *42*(5), pp. 533-544.

Pachler, N., Bachmair, B., & Cook, J. (2010). *Mobile learning: Structures, Agency, Practices. In Mobile learning: Structures, Agency, Practices*. New York: Springer.

Pierce, R., Stacey, K., & Barkatsas, A. (2007). A scale for monitoring students' attitudes to learning mathematics with technology. *Computers & Education*, *48*(2), 285-300.

Pointon, A., & Sangwin, C. (2003). An analysis of undergraduate core material in the light of hand-held computer algebra systems. *International Journal of Mathematical Education in Science and Technology*, vol. *34*(5), pp. 671-686.

Presmeg, N., Radford, L, Roth, W., & Kadunz, G. (2016). Semiotics in Theory and Practice in Mathematics Education. In *Semiotics in Mathematics Education* (pp. 5-29). Springer International Publishing.

Punch, K. (2009). Qualitative research design. *Introduction to research methods in education. Newcastle Upon Tyne, UK: Sage*.

Raj, L. (2011). Focusing learning on concepts of introductory linear algebra using Maple interactive tutors. *Department of Mathematics and Statistics, Zayed University, United Arab Emirates*.

Razzaq, L., Mendicino, M., & Heffernan, N. (2008). Comparing classroom problem-solving with no feedback to Web-based homework assistance. In *Intelligent Tutoring Systems* (pp. 426-437). Springer: Berlin Heidelberg.

Ritter, S., Anderson, J. R., Koedinger, K. R. & Corbett, A. (2007). Cognitive Tutor: Applied research in mathematics education. *Psychonomic bulletin & review,* Vol. *14*(2), pp. 249-255.

Roschelle, J. (2003). Keynote paper: Unlocking the learning value of wireless mobile devices. *Journal of Computer Assisted Learning*, vol. 19(3), pp. 260-272.

Sabo, K., Atkinson, R., Barrus, A., Joseph, S., & Perez, R. (2013). Searching for the two sigma advantage: Evaluating algebra intelligent tutors. *Computers in Human Behavior*, vol. *29*(4), pp. 1833-1840.

Schneider, M., Egan, K., & Julian, M. (2013). Classroom assessment in the context of high-stakes testing. In J. McMillan (Ed.), *SAGE handbook of research on classroom assessment.* (pp. 55-71). Thousand Oaks, SAGE Publications Inc: CA

Schoenfeld, A. (1992). Learning to think mathematically: Problem solving, metacognition, and sense making in mathematics. *Handbook of research on mathematics teaching and learning*, pp. 334-370.

Schommer-Aikins, M., Duell, O. K., & Hutter, R. (2005). Epistemological beliefs, mathematical problem-solving beliefs, and academic performance of middle school students. *The Elementary School Journal*, *vol. 105*(3), pp. 289-304.

Sharples, M., Taylor, J., & Vavoula, G. (2006). A Theory of Learning for the Mobile Age. *The Sage Handbook of E-learning Research*, pp. 221-247.

Sharan, M. (2009). *Qualitative Research: A Guide to Design and Implementation (2nd ed.)* San Francisco, CA: Jossey-Bass.

Shepard, L (2000). The role of assessment in a learning culture. *Educational researcher*, vol. 29(7), pp. 4-14.

Shield, M., & Dole, S. (2013). Assessing the potential of mathematics textbooks to promote deep learning. *Educational Studies in Mathematics*, vol. *82*(2), pp. 183-199.

Shute, V. & Underwood, J. (2006). Diagnostic assessment in mathematics problem solving. *Technology instruction cognition and learning*, vol. *3*(1/2), pp. 151-166.

Siemens, G. & Long, P. (2011). Penetrating the Fog: Analytics in Learning and Education. E*DUCAUSE review*, vol. *46*(5), pp. 30-40.

Stiggins, R., & Chappuis, J. (2005). Using student-involved classroom assessment to close achievement gaps. *Theory into practice*, vol. *44*(1), pp.11-18.

Smith, C,& Santori, D. (2015). An Exploration of iPad-Based Teaching and Learning: How Middle-Grades Teachers and Students Are Realizing the Potential. *Journal of Research on Technology in Education*, vol. *47*(3), pp. 173-185.

Steinbring, H. (2005). *The construction of new mathematical knowledge in classroom interaction: An epistemological perspective* (Vol. 38). Springer Science & Business Media.

Stewart, S., Thomas, M., & Hannah, J. (2005). Towards student instrumentation of computer-based algebra systems in university courses. *International Journal of Mathematical Education in Science and Technology*, vol. 36(7), pp.741-749.

Swidan, O., & Yerushalmy, M. (2016). Conceptual structure of the accumulation function in an interactive and multiple-linked representational environment. *International Journal of Research in Undergraduate Mathematics Education*, vol. *2*(1), pp. 30-58.

Tall, D. (2000). Cognitive development in advanced mathematics using technology. *Mathematics education research journal*, vol. *12*(3), pp. 196-218.

Tall, D. (2009). Dynamic mathematics and the blending of knowledge structures in the calculus. *ZDM*, *41*(4), 481-492.

Tan, H. (2009). Development of an instrument for ways of using graphics calculators: Preliminary findings. *Crossing divides*, pp. 531-538.

Tennyson, R. (2010). Historical reflection on learning theories and instructional design. *Contemporary education technology, vol. 1*(1), pp. 1-16.

Taylor, R. (2011). Supporting developments within a local authority. In A. Oldknow, & C. Knights (Eds.), *Mathematics Education with digital technology* (pp. 241-250). London: Continuum International Publishing Group.

Teddlie, C., & Sammons, P. (2010). Methodological advances in educational effectiveness research. In B. Creemers, L. Kyriakides, P. Sammons, & G. Marcoulides (Ed.), *Methodological advances in educational effectiveness research* (pp. 115-152). New York: Routledge.

Tempelaar, D., Rienties, B., & Giesbers, B. (2011). Student learning preferences in a blended learning environment: Investigating the relationship between tool use and learning approaches. In *Building learning experiences in a changing world* (pp. 195-212). Springer Netherlands.

Thelwall, M. (2000). Computer-based assessment: a versatile educational tool. *Computers & Education*, vol. *34*(1), pp. 37-49.

Thomas, M., & Hong, Y. (2004). Integrating CAS calculators into mathematics learning: partnership issues. In *Proceedings of the 28th Conference of the International* vol. 4, pp. 297-304.

Trautwein, U., & Köller, O. (2003). The relationship between homework and achievement—still much of a mystery. *Educational psychology review*, vol. *15*(2), pp. 115-145.

Trouche, L. (2005). An instrumental approach to mathematics learning in symbolic calculator environments. In *The didactical challenge of symbolic calculators* vol. 36, pp. 137-162. Springer US.

Trouche , L., & Drijvers, P. (2010). Handheld technology for mathematics education: Flashback into the future. *ZDM*, vol. 42(7), pp. 667-681.

Uden, L. (2007). Activity theory for designing mobile learning. *International Journal of Mobile Learning and Organization*, vol. *1*(1), pp. 81-102.

VanLehn, K. (2011). The relative effectiveness of human tutoring, intelligent tutoring systems, and other tutoring systems. *Educational Psychologist*, vol. *46*(4), pp. 197-221.

Verillon, P., & Rabardel, P. (1995). Cognition and Artifacts: a contribution to the study of thought in relation to instrumented activity. *European Journal of Psychology of Education, vol. X*(1), pp. 77-101.

Verillion, P., & Andreucci, C. (2006). Artifacts and cognitive development: How do psychogenetic theories of intelligence help in understanding the influence of technical environment, *International Handbook of Technology Education: Reviewing the Past Twenty Years*, pp. 399-417.

Vygotsky, L. (1980). *Mind in society: The development of higher psychological processes*. Harvard university press.

Waits, B. K., & Demana, F. (2000). Calculators in mathematics teaching and learning: Past, present, and future. *Learning mathematics for a new century*, pp. 51-66.

Warner, R. M. (2008). *Applied statistics: From bivariate through multivariate techniques*. Sage: New York.

Williams, B., Brown, T., & Onsman, A. (2012). Exploratory factor analysis: A five-step guide for novices. *Australasian Journal of Paramedicine*, vol. *8*(3), pp. 1-16.

Wood, D., & Wood, H. (1996). Vygotsky, tutoring and learning. *Oxford review of Education*, vol. *22*(1), pp. 5-16.

Woolf, B., Burleson, W., Arroyo, I., Dragon, T., Cooper, D. & Picard, R. W. (2009). Affect-aware tutors: recognising and responding to student affect. International Journal of Learning Technology, vol 4(3/4), pp. 129– 164.

Xin, Y., Tzur, R., Hord, C., Liu, J., Park, J., & Si, L. (2017). An Intelligent Tutor-Assisted Mathematics Intervention Program for Students With Learning Difficulties. *Learning Disability Quarterly*, 0731948716648740.

Yeongeong , P. (2011). A pedagogical framework for mobile learning: Categorizing educational applications of mobile technologies into four types. The International Review of Research in Open and Distance Learning, vol. 12(2), pp. 78-102.

Yorke, M., & Longden, B. (2004). *Retention and student success in higher education*. McGraw-Hill International.

Yukselturk, E., & Bulut, S. (2009). Gender differences in self-regulated online learning environment. *Educational Technology & Society*, vol. *12*(3), pp. 12-22.

Wali, E., Oliver, M., & Winters, N. (2009). Are they doing what they think they're doing? Tracking and triangulating students' learning activities and self-reports. In G. Vavoula, N. Pachler, & A. Kukulska-Hulme (Eds.), Researching mobile learning: Frameworks, Tools and Research Designs (pp. 316-335). Berlin: Peter Lang International Academic Publisher.

Zurita, G., & Nussbaum, M. (2007). A conceptual framework based on activity theory for mobile CSCL. *British Journal of Educational Technology*, vol. *38*(2), pp. 211-235.

Zualkernan, I. (2015). Gender differences in a technology-based numeracy intervention in a developing country. In *Global Humanitarian Technology Conference (GHTC), 2015 IEEE* (pp. 414-419). IEEE.

Appendix -1

Data log – learning activities

Figure A-1: ALEKS data log showing student's learning activities

Report from 08/27/2016 to 08/29/2016 (Change Date Range)

Refresh Report

Date	Time Spent in ALEKS	Topics Attempted	Topics Mastered
Mon 08/29/2016	12 minutes	2 topics	2 topics

Learning Sequence Log on 08/29/2016

Time	Result
Learning:	**Translating a phrase into a one-step expression**
9:35:32 PM	Wrong
9:35:35 PM	Explain
9:37:09 PM	Wrong
9:37:27 PM	Correct
9:37:47 PM	Correct
9:38:01 PM	Correct
9:38:22 PM	Added to Pie
Learning:	**Translating a phrase into a two-step expression**
9:39:24 PM	Wrong
9:39:28 PM	Explain
9:40:09 PM	Explain
9:40:41 PM	Correct
9:41:16 PM	Wrong
9:41:19 PM	Explain

Student’s survey instrument

Table A1-1: Student survey instrument

Please provide your HCT student number: --------------

Section A: Demographics

Please provide the following information. Please circle one option that is applicable to you.

(1) Select your gender: (a) Female (b) Male

(2) Which course are you enrolled in now?

(a) M010 (b) M020 (c) M030 (d) Other

Section B: Close ended questions

Part I

For each statement please put a √ mark in column which most closely corresponds to your opinion.

Item no	**Item description**	**Strongly agree 1**	**Agree 2**	**Neutral 3**	**Disagree 4**	**Strongly disagree 5**
1	ALEKS helps me improve my understanding of mathematics problems.					
2	ALEKS helps me visualize the problems.					
3	I can solve the problem using ALEKS even though I don’t understand the theory.					
4	ALEKS helps me to concentrate on understanding the concepts of the course.					

Item no	**Item description**	**Strongly agree 1**	**Agree 2**	**Neutral 3**	**Disagree 4**	**Strongly disagree 5**
5	ALEKS encouraged me to think for myself.					
6	ALEKS encouraged the development of my knowledge.					
7	ALEKS made helpful comments on my work.					
8	ALEKS provided helpful feedback on my work.					
9	ALEKS sensed when I needed help.					
10	Due to ALEKS, my interest in mathematics is increased.					
11	I believe many mathematics courses could be improved by the use of programs like ALEKS.					
12	Using computers to teach mathematics is a bad idea.[4]					
13	Computer programs like ALEKS can do a lot more teaching than I had expected.					
14	It is a waste of time using ALEKS for learning mathematics.					
15	Computer programs like ALEKS can show students what is important to learn.					

[4] Items shown in red color are negative worded.

Item no	Item description	Strongly agree 1	Agree 2	Neutral 3	Disagree 4	Strongly disagree 5
16	I prefer to learn from a human tutor than a computer program like ALEKS.					
17	I like ALEKS because I can learn independently.					
18	ALEKS is easy to use.					
19	ALEKS provided me with detailed explanation.					
20	ALEKS helped me master topics in advance.					
21	ALEKS is enjoyable and stimulating.					
22	ALEKS is good for revising what I learn in class.					
23	All calculations should be done on a calculator or by using some app.					
24	It is not necessary to solve a problem step by step on paper when you can use some app on iPad for problem solving.					
25	I believe that all problems can only be solved using a calculator and iPad.					
26	Since I have been using a calculator I have forgotten how to solve problems without it.					

Item no	Item description	Strongly agree 1	Agree 2	Neutral 3	Disagree 4	Strongly disagree 5
27	I am not as confident in solving mathematics problem at home as I am in the classroom..					
28	It is not necessary to solve as many problems given on ALEKS to master a topic.					
29	ALEKS taught me how to solve real life problems using mathematics.					

Part II

For each statement please put a √ mark in column which most closely corresponds to your opinion.

Item no	Item description	Always 1	Very often 2	Sometimes 3	Rarely 4	Never 5
1	I use the same app that my teacher uses in the class.					
2	I explore and find different apps for different topics.					
3	I solve each problem on a paper step by step.					
4	I take notes in class and refer to them while revising with ALEKS.					
5	My answers are usually different from the answers that the ALEKS gives me.					

Item no	Item description	Always 1	Very often 2	Sometimes 3	Rarely 4	Never 5
6	I give up when I fail to master a topic on my own.					
7	I ask for help from my teacher or friend when I fail to master a topic.					
8	I check for some videos on YouTube when I fail to master a topic.					
9	I watch the videos recommended by my teacher.					
10	I master a slice on ALKES pie only when my teacher tells me to do so.					
11	I master each slice completely then move to the next slice as shown on the PIE.					
12	Before solving a question on ALEKS, I read the given explanation.					
13	I review all topics that I completed on ALEKS before every exam.					
14	I waste a lot of time using other irrelevant activities, such as, watching movies, on the iPad.					
15	I check if my answer is reasonably correct and sensible.					

Section C: Open questions

(1) Write the names of all topics for which you found iPad useful and write the names of the apps that you used for each topic. Why do you think these apps were helpful? You may complete the following table.

Topic in mathematics	The app that made the topic easy for you	Reason why you found the app helpful

Student survey instrument- Factor loading details

Table A1-2: Students survey: Factor loading and reliability scores

Item no	Item description	Description, Factor label and variable name	Factor loading score	Factor Reliability score	Source of the item[5]
Part -1: Items measuring perceptions and beliefs					
7	ALEKS made helpful comments on my work.	Perceptions about Tutoring effect of ALEKS. Variable name: *Factor1*	0.83	0.89	Adcock, & Eck, (2005)
8	ALEKS provided helpful feedback on my work.		0.84		
19	ALEKS provided me with detailed explanation.		0.80		
9	ALEKS sensed when I needed help.		0.80		
17	ALEKS allows me to learn independently.		0.87		

[5] Items are modified to suit to the chosen tool

Item no	**Item description**	**Description, Factor label and variable name**	**Factor loading score**	**Factor Reliability score**	**Source of the item[5]**
20	ALEKS helped me master topics in advance.		0.77		McArthur & Stasz(1989)
22	ALEKS is good for revising what I learn in class.		0.75		New
10	Due to ALEKS, my interest in mathematics is increased.	*Perceptions about usability and effect of ALEKS on interest in mathematics.* Factor label: *Affect* Variable name: *Factor2*	0.85	0.79	Adcock, & Eck, (2005)
21	ALEKS is enjoyable and stimulating.		0.82		
18	ALEKS is easy to use.		0.71		
29	ALEKS taught me how to solve real life problems using mathematics.		0.58		
1	ALEKS helps me improve my understanding of mathematics problems.	Perceptions about Effect of ALEKS on their Mathematics understanding. Abbreviated as *Cognitive effect* *Variable name: Factor3*	0.72	0.67	Adcock, & Eck, (2005)
5	ALEKS encouraged me to think for myself.		0.83		Adcock, & Eck, (2005)
6	ALEKS encouraged the development of my knowledge.		0.79		
2	ALEKS helps me visualize the problems.		0.75		
3	I can solve the problem using ALEKS even though I don't understand the theory.		0.68		Stewart, Thomas, &

Item no	**Item description**	**Description, Factor label and variable name**	**Factor loading score**	**Factor Reliability score**	**Source of the item[5]**
					Hannah, 2005).
4	ALEKS helps me to concentrate on understanding the concepts of the course.		0.84		
15	Computer programs like ALEKS can show students what is important to learn.	Perceptions about use of computer tutors in learning Mathematics. *Variable name: Factor4*	0.68	0.68	McArthur & Stasz(1989)
13	Computer programs like ALEKS can do a lot more teaching than I had expected.		0.82		
16	I prefer to learn from a human tutor than a computer program like ALEKS.		0.72		McArthur & Stasz(1989)
11	I believe many mathematics courses could be improved by the use of programs like ALEKS.		0.70		
12	Using computers to teach mathematics is a bad idea.		0.65		
14	It is a waste of time using ALEKS for learning mathematics.		0.75		
26	Since I have been using a calculator I have forgotten how to solve problems without it.	Beliefs about learning with digital tools.	0.68	0.68	Stewart, Thomas, &

Item no	**Item description**	**Description, Factor label and variable name**	**Factor loading score**	**Factor Reliability score**	**Source of the item**[5]
		Variable name:			Hannah, 2005).
28	It is not necessary to solve as many problems given on ALEKS to master a topic.	*Factor5*	0.87		
24	It is not necessary to solve a problem step by step on paper when you can use some app on iPad for problem solving.		0.68		
27	I am not as confident in solving mathematics problem at home as I am in the classroom.		0.58		
23	All calculations should be done on a calculator or by using some app.		0.68		
25	I believe that all problems can only be solved using a calculator and iPad.		0.87		
Part – 2: Items measuring study habits					
Item no	Item description	Factor Label	Factor loading	Reliability score	Source
1	I use the same app that my teacher uses in the class.	Systematic study habits	0.60	0.676	
2	I explore and find different apps for different topics.	Variable name: *Study habit1*	0.63		

Item no	Item description	Description, Factor label and variable name	Factor loading score	Factor Reliability score	Source of the item[5]
3	I solve each problem on a paper step by step.		0.64		
4	I take notes in class and refer to them while revising with ALEKS.		0.79		
15	I check if my answer is reasonably correct and sensible.		0.64		
7	I ask for help from my teacher or friend when I fail to master a topic.	Seeking External help Variable name: *Study habit2*	0.52	0.643	
8	I check for some videos on YouTube when I fail to master a topic.		0.88		
9	I watch the videos recommended by my teacher.		0.84		
10	I master a slice on ALKES pie only when my teacher tells me to do so.	Systematic use of tools Variable name: *Study habit3*	0.60	0.664	New
11	I master each slice completely then move to the next slice as shown on the PIE.		0.75		
12	Before solving a question on ALEKS, I read the given explanation.		0.76		
13	I review all topics that I completed on ALEKS before every exam.		0.71		

Item no	**Item description**	**Description, Factor label and variable name**	**Factor loading score**	**Factor Reliability score**	**Source of the item[5]**
5 **6**	My answers are usually different from the answers that the ALEKS gives me. I give up when I fail to master a topic on my own.	Persistence Variable name: *Study habit4*	0.83 0.7	0.72	New
14	I waste a lot of time using other irrelevant activities, such as, watching movies, on the iPad.	Distraction Variable name: *Study habit5*	Single item factor 0.833[6]		Stewart, Thomas, & Hannah,

[6] This is left as a single item factor due to the high factor loading score.

Teacher survey instrument- with factor loading details

Table A1-3: Teachers survey: Factor loading and reliability

Item description	Factor name	Factor loading	Reliability	Source
Part- I Frequency of iPad usage for administrative and teaching tasks				
How often do you use iPad to mark attendance?	Administrative tasks	.936	0.949	Adapted from Becker and Anderson (1998)
How often do you use iPad for grading students' assignments?		.926		
How often do you use iPad to prepare study material?		.931		
How often do you use iPad to prepare interactive assignments?		.937		New
How often do you use iPad to give oral feedback on students' assignments?	Teaching tasks	.879	0.842	
How often do you use iPad to give written feedback on students' assignments?		.924		
How often do you use iPad to create e-books?		.792		
How often do you use iPad for in class group work?		.685		
Part-II: Perceptions about benefits and limitations of iPads				
Students find it easy to do complex calculations using some apps on the tablet	Benefits of using iPad as a teaching tool	0.865	0.864	New
Students find it easy to do mathematics constructions, such as drawing graphs or simulating probability distributions		0.825		
Some mathematical apps on the tablet computers facilitate students' learning of abstract mathematical concepts		0.809		
Students find it easy to collaborate with each other using tablets.		0.915		

Item description	Factor name	Factor loading	Reliability	Source
Students waste a lot of time doing unnecessary and irrelevant tasks on the tablet	Limitations of using iPad as a teaching tool	.821	0.871	
Students solve problems mechanically but do not understand the mathematical concepts underlying the		.810		
Use of any digital device such as tablet hampers students learning ability		.860		
Students find it difficult to learn how to use mathematical apps		.522		
Students find it hard to solve problems on the tablet		.851		
It is hard for teachers to provide feedback on students' work which is done using tablet		.806		
Part III: Ranking important features of iPad in teaching mathematics and the actual implementation of these features				
Developing Strategy	Actual use of iPad as a teaching tool	.810	0.806	New
Facilitating Understanding		.661		
Providing Visual representation		.775		
Giving ample practice to master a concept		.799		
Mobile learning		.693		
Fostering Collaboration		.569		
Part IV: Preference of utilizing technology specific to a topic in the module[7]				
In your opinion, for each of the following topics, which method is more suitable? Traditional teaching method (in which *no* digital handheld device is used), contemporary method (using a suitable app or a program only) or a combination of both methods?				
Name of the topic	Traditional method *not at all* supported by use of	Traditional method supported by *moderate* use of technology	Traditional method supported by *high* usage of technology	Using a suitable app or program only, *no traditional*

[7] Factor loading and reliability scores are not applicable for items in this part

Item description	Factor name	Factor loading	Reliability	Source
Solving equations in one variable				
Solving a system of equations				
Line graphs				
Problems in perimeter/area/ volume				
Application of percentages				
Exponents				
Statistics				
Probability				

Appendix-2: Class observation

Coding sheet used for class observation

Table A2-1: Coding sheet for class observation

Time slots in minutes / → Type of interaction ↓	0-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50
$S - S$										
$S - Ss$										
$S - T$										
$T - Ss$										
$T - S$										
$T - Tl$ Su: Support Ex: Extend Tr: Transform										
$S - Tl$ Ma: Master Se: Servant Pa: Partner Et: Extension										
$S - M$ C: Calculator D: Dictionary (Translator) Sn: Study notes										

Observation -1.

Table A2-2: Class details – Observation -1

Course details	Course: M010 / Topic: Geometry
Student demographic details	There were 15 boys in the age group of 17-25 years. They are learning English as their second language and have low level proficiency in English.
Physical setting and time of the day	Setting: Lesson was delivered in a small classroom. Students sat according to their own preference.
	Time: 9:00 pm to 9:50 am
Expected outcomes	After the lesson, students are expected to (1) understand mathematical meaning of the terms: solid shapes, nets of shapes (2) Apply their understanding to solve relevant problems
Observed Activity	This was a problem solving session. The students watched the demonstration of the app for the first 10 min. Then the teacher asked them to solve a classwork assignment on ALEKS. This classwork had questions about identifying names of solid shapes and nets of solids. The students did not appear to be engaged in the problem solving activity. They were checking the Arabic translation using Google Translate. ALEKS graded their work and they could see their grades immediately. It was noticed that none of them could solve all problems correctly. They were discussing problem solution with each other.
Physical tools used	Teacher's PC in the classroom
Digital tools and programs used by the teacher	Digital whiteboard cum projector screen, the app named *Shapes* and ALEKS.

Method of assessing learning outcome	Classwork exercises were set on ALEKS in which students could see the explanation if required. Due to randomization techniques of ALEKS, they all got different versions of the same questions.

Table A2-3: Observation data – Class-1

Time slots in minutes / → Type of interaction ↓	0-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50
$S - S$		√							√	
$S - Ss$										
$S - T$		√					√		√	
$T - Ss$	√							√		
$T - S$		√								
$T - Tl$ Su: Support Ex: Extend Tr: Transform	√ **Su**	√ **Su**	√ **Su**					√ **Su**		
$S - Tl$ Ma: Master Se: Servant			√ **Ma**	√ **Ma**	√ **Se**	√ **Se**	√ **Se**		√ **Ma**	√ **Se**

Pa: Partner Et: Extension										
$S - M$ C: Calculator D: Dictionary (Translator) Sn: Study notes	√ **Sn**				√ **D**				√ **Sn**	

Observation -2

Table A2-4: Class details – Observation -2

Course details	Course: M010 / Topic: Geometry
Student demographic details	There were 20 girls in the age group of 17-20 years. They are learning English as their second language and have moderate level proficiency in English.
Physical setting and time of the day	Setting: Lesson was delivered in a medium sized classroom and there were five seating clusters, each cluster accommodated four students. Students sat according to their own preference in five groups.
	Time: 10:00 am to 10:50 am
Expected outcomes	After the lesson, students were expected to • understand the following: mathematical meaning of the terms: - solid shapes, nets of shapes other properties: edges, faces, vertices - Difference between the two and three dimensional shapes - Concepts of area, surface area and volume of plane and solid shapes • apply their understanding to solve problems
Observed Activity	Tutorial followed by a problem solving session
Physical tools used	Teacher's PC in the classroom
Digital tools and programs used by the teacher	Digital whiteboard cum projector screen, the app named *Nearpod*, resources and applets available on the *www.mathisfun.com* and ALEKS.

Method of assessing learning outcome	• During the tutorial session, students had to complete the worksheets. They watched the animation for each shape and noted its properties. • During problem solving session, students were given problems from ALEKS on a paper worksheet. They could see their answers only after completing them. This prevented them from manipulation of answers. • Due to the printed version, all students got the same version of each problem

Table A2-5: Observation data – Class– 2

Time slots in minutes / → Type of interaction ↓	0-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50
$S-S$									√	
$S-Ss$		√		√	√	√	√			√
$S-T$		√					√		√	
$T-Ss$	√	√						√		
$T-S$		√		√						
$T-Tl$ Su: Support Ex: Extend Tr: Transform	√ **Ex**	√ **Ex**	√ **Ex**							

$S - Tl$ Ma: Master Se: Servant Pa: Partner Et: Extension			√ **Ma**	√ **Ma**	√ **Se**	√ **Se**	√ **Se**		√ **Se**	√ **Se**
$S - M$ C: Calculator D: Dictionary (Translator) Sn: Study notes F: Formula sheet	√ **Sn**	√ **M**						√ **F** **Se**	√ **Sn** **Se**	

Observation-3

Table A2-6: Class details – Observation -3

Course details	Course: M030 / Topic: Exponents
Student demographic details	There were 15 girls in the age group of 17-20 years. They are learning English as their second language and have moderate level proficiency in English. These students have met the eligibility criteria for English language proficiency and they will be joining Engineering major in the following semester. Overall these students have a better aptitude towards mathematics than students observed in other two classes.
Physical setting and time of the day	Setting: Lesson was delivered in a medium sized classroom with a typical lecture style seating arrangement. Students sat according to their own preference in any row. One student preferred to sit alone in the last row.
	Time: 1:00 pm to 1:50 pm

Expected outcomes	After the lesson, students will understand the following: mathematical meaning of the terms: • Rational exponents • Simplification of expressions with real exponents They will apply their understanding to solve problems
Observed Activity	Tutorial followed by a problem solving session
Physical tools used	Teacher's PC in the classroom, non-digital whiteboard
Digital tools and programs used by the teacher	Digital whiteboard cum projector screen, PowerPoint and ALEKS.
Method of assessing learning outcome	• During the tutorial session, the teacher wrote a step by step solution on the whiteboard and students wrote those steps in their notebook. • During the problem solving session, students were given problems from ALEKS on a paper worksheet in which answers were given with the problems to verify. • Due to the printed version, all students got the same version of each problem

Table A2-7: Observation data – Class– 3

Time slots in minutes / → Type of interaction ↓	0-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50
$S-S$				√	√	√	√		√	
$S-Ss$										
$S-T$							√		√	
$T-Ss$	√	√			√	√		√		
$T-S$		√		√					√	
$T-Tl$ Su: Support Ex: Extend Tr: Transform	√ **Su**	√ **Su**	√ **Su**							
$S-Tl$ Ma: Master Se: Servant P: Partner E: Extension			√ **Ma**	√ **Ma**					√ **Se**	√ **Se**
$S-M$ C: Calculator D: Dictionary (Translator)	√ **Sn**	√ **Ma**	√ **C**	√ **C**	√ **Se**	√ **Se**	√ **Se**	√ **F**	√ **Sn**	

Sn: Study notes F: Formula sheet				**Sn**				**Se**	**Se**	

Appendix-3: SPSS output

1. Reliability: Students survey

Table A3-1: Reliability analysis-students survey – Part-1

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.929	.935	29

Table A3-2: Reliability analysis-students survey - Part-2

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.761	.763	15

2. Reliability analysis – Teachers survey

Table A3-3: Reliability analysis-teachers survey - Part-1

Reliability Statistics	
Cronbach's Alpha	N of Items
.821	10

Table A3-4: Reliability analysis-teachers survey - Part-2

Reliability Statistics	
Cronbach's Alpha	N of Items
.821	10

3. Sample size adequacy

Table A3-5: KMO Bartlett's test – Student survey - Part-1

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.922
Bartlett's Test of Sphericity	Approx. Chi-Square	3460.541
	df	406
	Sig.	.000

Table A3-6: KMO Bartlett's test – Student survey - Part-2

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.754
Bartlett's Test of Sphericity	Approx. Chi-Square	636.111
	df	105
	Sig.	.000

4. Test of normality

Table A3-7: Test of normality: Students survey

Tests of Normality						
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Tutoring effect of ALEKS	.145	154	.000	.914	154	.000
Affect	.145	154	.000	.914	154	.000
Cognitive effect of ALEKS	.093	154	.003	.949	154	.000
Use of tools- Perceptions	.125	154	.000	.968	154	.001

Beliefs	.098	154	.001	.985	154	.085
Systematics study habits	.138	154	.000	.918	154	.000
External help	.130	154	.000	.960	154	.000
Systematic use of tools- Practice	.087	154	.006	.963	154	.000
Persistence	.099	154	.001	.962	154	.000
Distractions	.203	154	.000	.869	154	.000

5. Two independent samples test

Table A3-8: Two independent samples test

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of Systematic study habits is the same across categories of Course Number.	Independent-Samples Kruskal-Wallis Test	.304	Retain the null hypothesis.
2	The distribution of External help seeking habit is the same across categories of Course Number.	Independent-Samples Kruskal-Wallis Test	.963	Retain the null hypothesis.
3	The distribution of Habits of using ALEKS is the same across categories of Course Number.	Independent-Samples Kruskal-Wallis Test	.326	Retain the null hypothesis.
4	The distribution of Persistence and ways to cope with failure is the same across categories of Course Number.	Independent-Samples Kruskal-Wallis Test	.000	Reject the null hypothesis.
5	The distribution of Resistance to distraction is the same across categories of Course Number.	Independent-Samples Kruskal-Wallis Test	.251	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

6. Three independent samples test

Table A3-9: Three independent samples test

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of Perceptions about tutoring effects of ALEKS is the same across categories of Course Number.	Independent-Samples Kruskal-Wallis Test	.769	Retain the null hypothesis.
2	The distribution of Perceptions about usability and effect of ALEKS on interest in mathematics. is the same across categories of Course Number.	Independent-Samples Kruskal-Wallis Test	.240	Retain the null hypothesis.
3	The distribution of Perceptions about Effect of ALEKS on their Mathematics understanding. is the same across categories of Course Number.	Independent-Samples Kruskal-Wallis Test	.421	Retain the null hypothesis.
4	The distribution of Perceptions about use of computer tutors in learning Mathematics. is the same across categories of Course Number.	Independent-Samples Kruskal-Wallis Test	.140	Retain the null hypothesis.
5	The distribution of Beliefs about learning with tools is the same across categories of Course Number.	Independent-Samples Kruskal-Wallis Test	.005	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

7. Output of Cluster analysis

Table A3-10: Output of cluster analysis

Clusters

Input (Predictor) Importance

1.0 0.8 0.6 0.4 0.2 0.0

Cluster	1	2	3
Label			
Description			
Size	36.4% (56)	33.1% (51)	30.5% (47)
Inputs	Timeinhours 63.23	Timeinhours 30.46	Timeinhours 34.33
	Ratio of mastered to practiced - Effort 0.67	Ratio of mastered to practiced - Effort 0.63	Ratio of mastered to practiced - Effort 0.81

8. Goodness of fit of the operational model

Table A3-11: Goodness of fit

Chi square statistic	p-value of the statistic	NFI	CFI
2.991	0.886	1.000	1.000

9. Output of path analysis

Table A3-12: Output of path analysis

To <--- From			Estimate	P Significance	Standardized Direct effect	Standardized Total effect
Shabit1	<---	Shabit3	.441	***	.475	0.475
Factor1	<---	Shabit3	.143	.042	.160	0.360
Factor1	<---	Shabit1	.404	***	.421	0.421
mtop	<---	Factor1	-.017	.267	-.103	-0.103
mtop	<---	Shabit3	.028	.035	.193	0.108
mtop	<---	Shabit1	-.016	.311	-.100	-0.143
Factor3	<---	Shabit1	-.012	.828	-.014	0.283
Factor3	<---	Factor1	.625	***	.705	0.705
Factor3	<---	Shabit3	.089	.070	.112	0.359
AleksScore	<---	Factor1	-4.890	.028	-.178	-0.240
AleksScore	<---	Shabit1	-.128	.955	-.005	-0.148
AleksScore	<---	Shabit3	-.774	.695	-.031	-0.018
AleksScore	<---	mtop	79.676	***	.472	0.472

10.Cumulative percent variation – Student survey – part -1

Table A3-13: Cumulative Percent variations – Students survey – part -1

Total Variance Explained						
Component	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	11.730	40.449	40.449	10.941	37.728	37.728
2	2.900	10.000	50.449	2.740	9.449	47.177
3	1.301	4.485	54.934	1.840	6.345	53.522
4	1.097	3.783	58.717	1.293	4.459	57.981
5	1.038	3.581	62.297	1.252	4.316	62.297
6	.957	3.298	65.596			

Total Variance Explained						
Component	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
7	.840	2.897	68.492			
8	.801	2.763	71.255			
9	.735	2.533	73.788			
10	.718	2.475	76.263			
11	.703	2.423	78.686			
12	.592	2.043	80.729			
13	.553	1.907	82.635			
14	.504	1.739	84.374			
15	.466	1.608	85.982			
16	.443	1.529	87.511			
17	.428	1.477	88.988			
18	.394	1.357	90.345			
19	.387	1.336	91.681			
20	.342	1.180	92.861			
21	.318	1.097	93.957			
22	.300	1.035	94.992			
23	.290	.998	95.990			
24	.255	.881	96.871			
25	.227	.781	97.652			
26	.197	.680	98.332			
27	.188	.650	98.982			

Total Variance Explained						
Component	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
28	.164	.565	99.547			
29	.131	.453	100.000			
Extraction Method: Principal Component Analysis.						

Table A3-14: Cumulative Percent variations – Students survey – part -2

Total Variance Explained						
Component	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.766	25.108	25.108	2.427	16.178	16.178
2	1.832	12.216	37.324	2.159	14.392	30.570
3	1.309	8.724	46.048	1.847	12.313	42.883
4	1.052	7.013	53.061	1.527	10.178	53.061
5	.976	6.509	59.571			
6	.934	6.229	65.799			
7	.862	5.745	71.544			
8	.786	5.237	76.782			
9	.703	4.685	81.467			
10	.599	3.995	85.461			
11	.555	3.699	89.161			
12	.518	3.452	92.613			
13	.424	2.828	95.441			

14	.386	2.570	98.011			
15	.298	1.989	100.000			
Extraction Method: Principal Component Analysis.						

Appendix 4: Ethical consideration form

Please provide details on the following aspects of the research:

1. What are your intended methods of recruitment, data collection and analysis?

Please outline (100-250 words) the methods of data collection with each group of research participants.

Two methods of data collection will be followed: survey and observation. Targeted population consists of teachers who are teaching Mathematics are introductory undergraduate level (Foundation or year 1) in UAE. Survey questionnaires to teachers will be sent by email. These participating teachers will be further requested to select their classes for observation. Students who are experiencing mobile learning will be asked to complete another survey.

2. How will you make sure that all participants understand the process in which they are to be engaged and that they provide their voluntary and informed consent? If the study involves working with children or other vulnerable groups, how have you considered their rights and protection?

   The study involves adult only and written explanation will be provided in English and Arabic (if required). During a personal meeting with them, it will be explained to them that they will be participating in a group and their identity and opinions will not be revealed to anyone. During the same conversation a quick question will be asked if they understood their role and their rights.

3. How will you make sure that participants clearly understand their right to withdraw from the study?

It will be explained to them in writing in English and Arabic (if required). During a personal meeting with them, a quick question will be asked if they their right to withdraw at any stage.

4. Please describe how you will ensure the confidentiality and anonymity of participants. Where this is not guaranteed, please justify your approach.

   In the teacher's survey, teacher must provide name and contact details because they will be further participating in observation. In the questionnaire, they will be asked if they can be contacted for further research. In the reporting, their names and locations will not be revealed. During class observations, students are identified with codes and not by their names or student id numbers.

5. Describe any possible detrimental effects of the study and your strategies for dealing with them.

   There will not have any detrimental effect of the study.

6. How will you ensure the safe and appropriate storage and handling of data?

   Data encoded manually during observation, will be immediately scanned and stored digitally. All digital data, including videos of observation will be stored on the laptop as well as on two more secondary storage devices, such as CD.

7. If during the course of the research you are made aware of harmful or illegal behaviour, how do you intend to handle disclosure or nondisclosure of such information (you may wish to refer to the BERA Revised Ethical Guidelines for Educational Research, 2004; paragraphs 27 & 28, p.8 for more information about this issue)?

   Not sure about this.

8. If the research design demands some degree of subterfuge or undisclosed research activity, how have you justified this?

   There is no undisclosed research activity.

9. How do you intend to disseminate your research findings to participants?

   There will be discussion with participating teachers about the analysis of observations. They will be invited to give feedback on the proposed framework. A thank you note will be sent to all participants of observations in which they will be invited to get the outcome of the research.

Declaration by the researcher

I have read the University's Code of Conduct for Research and the information contained herein is, to the best of my knowledge and belief, accurate.

I am satisfied that I have attempted to identify all risks related to the research that may arise in conducting this research and acknowledge my obligations as researcher and the rights of participants. I am satisfied that members of staff (including myself) working on the project have the appropriate qualifications, experience and facilities to conduct the research set out in the attached document and that I, as researcher take full responsibility for the ethical conduct of the research in accordance with the Faculty of Education Ethical Guidelines, and any other condition laid down by the BUiD Ethics Committee.

Print name: Anita Dani

Signature: ADDani

Date: 30-April-2017

Declaration by the Chair of the School of Education Ethics Committee (only to be completed if making a formal submission for approval)

The Committee confirms that this project fits within the University's Code of Conduct for Research and I approve the proposal on behalf of BUiD's Ethics Committee.

Print name:

(Chair of the Ethics Committee)

Signature:

Date: 10-april-2017.

HIGHER COLLEGES OF TECHNOLOGY

كليات التقنية العليا

September 15, 2015

From: Dr. Matthew A. Robby, Chair
HCT Applied Research Ethics Panel

To: Anita Dani

Ethical Clearance/Project Approval in the HCT

Your research proposal and protocol details for your dissertation entitled "use of mobile devices in mathematics education: A case of higher education in the United Arab Emirates" has been evaluated by the HCT Applied Research Ethical Panel in accordance with the Standards for Protection of Human Subjects and HCT policies and guidelines.

The HCT-AREP finds that your research protocol poses no more than minimal risk. The research project has therefore received ethical clearance and it is approved to proceed in the HCT based on the protocol described. A copy of this approval will be kept on file. The project will be monitored by the HCT-AREP for any updates and potential changes.

Congratulations and good luck as you move forward with this research and with the data collection and writing stages of your dissertation!

Please feel free to contact us if you need any assistance.

Thanks and best regards,

Dr. Matthew A. Robby
UNESCO Chair in Applied Research in Education
HIGHER COLLEGES OF TECHNOLOGY -
SHARJAH COLLEGES

P.O. Box 7947
Sharjah, United Arab Emirates
tel +9716 5054 540
mobile +971 56 222 7458
website http://shct.hct.ac.ae

UNESCO
Chair Program