EFFECTS OF INTELLIGENT TUTORING SYSTEMS IN BASIC ALGEBRA COURSES ON SUBSEQUENT MATHEMATICS LECTURE COURSES

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EFFECTS OF INTELLIGENT TUTORING SYSTEMS IN BASIC ALGEBRA COURSES ON SUBSEQUENT MATHEMATICS LECTURE COURSES (168 pp.)

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The purpose of this study was to investigate how intelligent tutoring system ALEKS, which was implemented in remedial Basic Algebra courses, affected students' success in subsequent lecture courses and how former ALEKS students and instructors in lecture courses perceived ALEKS learning environment. ALEKS courses were delivered in emporium style: instructors were available to answer students' questions, while ALEKS guided students through online exercises individually based on their skills and knowledge.

The participants were students from four mathematics lecture courses and their instructors. Some students took remedial courses in ALEKS prior to the lecture courses while some students did not. The quantitative part of the study compared ALEKS and non-ALEKS students on the final examination and students' self-reported-preparedness. The qualitative part of the study discussed students' and instructors' perceptions of ALEKS based on student surveys and instructor interviews.

No difference between ALEKS and non-ALEKS students was found in final examination scores and self-reported-preparedness. Students rated learning experience in ALEKS emporium on average at 2.74 on the scale of one to five, with five being the highest. One third of students liked studying at their own pace and ALEKS content (they rated ALEKS emporium at 3.29), while one fourth claimed that "nothing was good" in emporium courses (they rated ALEKS emporium at 1.55). Although ALEKS emporium was very different from lecture courses, only one fifth of students reported changes in their study habits. The instructors did not observe any difference between ALEKS and non-ALEKS students and mentioned benefits of ALEKS-like tool for drill-and-practice. One instructor observed positive shifts in student attitude towards mathematics but advised longer study to be conducted to confirm this observation.

Providing a choice to students between online and lecture courses, while increasing the role of instructors in online courses, may result in better student satisfaction. Students could also be gradually trained to effectively use online resources. The design changes in ALEKS could include the replacement of the "pie" with the bar chart, different types of feedback, explanation of how assessments are done, and ability to revisit problems on assessments.

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CHAPTER I

INTRODUCTION

Problem Statement

Higher education is faced with a growing number of students every year but many of them are underprepared for college and college mathematics in particular. According to the ACT (American College Testing) report for 2011, only 45% of high school graduates are ready for mathematics at the college level, leaving 55% who may need to take remedial mathematics courses. Remedial (developmental) mathematics courses are basic mathematics courses, some of which do not even count towards a college degree. These courses ensure students have specific mathematical skills to enable them to take higher mathematics courses. The pressure to get students through these courses is significant because students who fail to complete developmental and required college-level mathematics cannot earn a college degree, and also have limited employment options (Hodara, 2011). Unfortunately, students typically come to remedial mathematics classes with not only poor mathematics skills but with poor study and organizational skills as well (Boser & Burd, 2009). For these reasons, high dropout rates and low achievement scores are typical of remedial mathematics courses, despite efforts to help students be successful. The passing rate in remedial mathematics courses is not tracked on a national level, but statistics provided by the U. S. Department of Education (2009) for the state of Florida indicates only 56.1% of students in remedial mathematics courses passed.

Higher education institutions attempt to address this persistent problem by constantly looking for new and better ways to deliver remedial courses. Recent advances in technology introduced completely online systems that offer individualized learning environments. These systems are called intelligent or adaptive tutors because they create a unique learning environment for each student and, as a student learns new topics, the tutoring system updates the learning environment and guides the student to new topics that the student is ready to learn. Characteristics of each student and his or her past performance are also often tracked and taken into account, which makes the learning process even more individualized and personalized. This is as if each student has a personal tutor that is available all the time. The result is a focused online learning experience that is a very valuable feature for a busy college student who often balances responsibilities for a job, school, and sometimes even family. Intelligent tutoring systems are promising, but the number of commercial solutions is still relatively small primarily due to development costs. As with all other technological advances, it can be expected that development costs will decrease over time and the number of intelligent tutors will grow.

Intelligent tutors strive to be as close to human tutors as possible, but that goal is complex. Different intelligent tutors use different adaptation methods, have different user interfaces, and are often created for a very specific content area. They also can be implemented in different ways into classes. The implementation differences are primarily imposed by the school environment and student demographics, so what works in one environment may be less effective in another.

By investigating the effects of current intelligent tutors we can enhance current implementations and at the same time fuel future development. The intelligent tutoring system described in this study is Assessment and Learning in Knowledge Spaces (ALEKS, 2012). ALEKS includes an online book, exercises, and examinations, and it was implemented in an emporium-style in remedial mathematics courses. Emporium-style course delivery has many flavors, but it is mainly characterized by replacing the lecture with online software and on-demand instructors' assistance. The students were required to work in ALEKS a certain number of hours both at school and at home; while at school, students had instructors available to answer their questions but there were no lectures. Other instructor tasks were to offer guidance on students' progress and to administer examinations.

ALEKS emporium replaced traditional lecture courses introducing a significant change for both students and instructors. As the first generation of ALEKS students reached subsequent lecture mathematics courses, it was possible to determine the effectiveness of ALEKS emporium from that perspective. Did the students learn enough in ALEKS to succeed in subsequent lecture courses? What were students' perceptions of the effectiveness of ALEKS courses after they left the ALEKS environment? Did instructors from lecture courses perceive any differences in knowledge and/or behavior between former ALEKS students and students who never took ALEKS courses? How did student or instructor observations relate to the general features of intelligent tutoring systems? What features of intelligent tutoring systems appeared to be most important to the students and instructors?

Purpose of the Study

The ultimate test of learning is students' performance once they leave a specific learning environment. In the case of basic mathematics courses delivered through the ALEKS emporium, subsequent lecture courses could be considered as a different learning environment because in ALEKS emporium there were no lectures and ALEKS was in charge of guiding the student through course content and examinations. The instructor's role in ALEKS emporium courses was to help students as needed and to administer exams. In subsequent lecture mathematics courses, the instructor was in charge of everything.

The purpose of this study was to evaluate ALEKS emporium by measuring student achievement in subsequent mathematics lecture courses, to investigate student and instructor perceptions of ALEKS features, and to discuss the results and ALEKS features from the perspective of intelligent tutors in general.

ALEKS in an emporium-style was recently implemented in the remedial mathematics courses at a large Midwestern University. After two semesters of ALEKS implementation in four half-semester Basic Algebra courses, the first generation of students who have completed the ALEKS curriculum was able to enroll in subsequent credit-bearing lecture mathematics courses. At that point it was possible to evaluate how well these students performed once they left the ALEKS environment and what features of intelligent tutors appeared to be most important to both students and instructors. The achievement of former ALEKS students was compared to the achievement of students who did not take courses in ALEKS. Results from a student survey as well as data from interviews with instructors were analyzed for possible strengths and/or weaknesses of ALEKS. ALEKS features were discussed from the perspective of intelligent tutors in general.

Research Questions

In the mathematics lecture courses included in this study, former ALEKS students were mixed with students who never took ALEKS courses. Students who did not take any Basic Algebra courses in ALEKS either scored high on a college placement test and placed directly into a lecture course, transferred appropriate credits from another college, took AP Calculus at high school, or took Basic Algebra courses before ALEKS emporium was introduced. Students from four different mathematics lecture courses participated in the study so that the effect of ALEKS on different mathematics lecture courses could be evaluated. Each lecture course was represented by two sections taught by the same instructor. Student self-reported-preparedness for the lecture course and satisfaction with ALEKS were collected through a student survey. The student survey is presented in Appendix A. The following research questions were answered:

1. Is there a difference in final examination scores between former ALEKS students and students who did not take ALEKS emporium courses?

2. Is there a difference in self-reported-preparedness between former ALEKS students and students who did not take ALEKS emporium courses?
3. What is the relationship between students' self-reported-preparedness for the lecture mathematics course and the final examination scores for former ALEKS students? What is the nature of the above relationship for students who did not take ALEKS courses?
4. How do former ALEKS students rate their ALEKS learning experience?
5. What is the relationship between the number of ALEKS courses taken and student satisfaction with their ALEKS learning experience?

Open-ended questions from the student survey about ALEKS were analyzed to answer the following questions:

6. What do students perceive as effective in ALEKS courses?
7. What do students perceive as ineffective in ALEKS courses?
8. How did ALEKS change student's learning and study habits?

The analysis of interviews with the instructors attempted to discover if the differences between former ALEKS students and students who did not take ALEKS courses were observable to instructors and what the differences were. Although the instructors did not know right from the start which students took ALEKS courses there was a possibility that during the semester they might have an idea who former ALEKS students were based on their performance or expectations and behavior.

The following questions were answered:

9. Where there observable differences in the knowledge between current student groups and the groups in the past and, if so, what they were? Did former ALEKS students show some common strengths or weaknesses?
10. Were there observable differences in students' behavior and expectations between ALEKS and non-ALEKS students and what they were? In other words, did the ALEKS environment affect students so that effects on the current course could be observed?
11. Were some adjustments necessary in lecture courses because of the former ALEKS students? If so, what and how effective were they?

Significance

The first national outcome goal for postsecondary education in the "Strategic Plan for Fiscal Years 2011-2014" report (U. S. Department of Education, 2012) was to increase the percentage of 25- to 34-year-olds who attain an associate's degree or higher. The United States had the highest proportion of college graduates in the world in the past and the President's goal is to restore that status by 2020. Significant government investments into higher education placed great responsibility on colleges to do their share and to deliver quality education which includes solid mathematics knowledge.

It is always important to evaluate learning outcomes but in the case of the implementation of new technology this is especially important because early feedback may trigger adjustments that will further improve learning outcomes. From that perspective this study might contribute to the decision-making at one educational institution by answering important questions about the implementation of a technology-based system in remedial mathematics courses. The study also provided instructors' and students' perspective that may be valuable in identifying important features of intelligent tutors.

Delimitations

Time of the study: August 2012 through December 2012.

Location of study: Regional campus of a large Midwestern university.

Sample of the study: eight college mathematics sections that follow remedial mathematics courses.

The Definition of Terms

ACT-R (Adaptive Control of Thought-Rational) - is a cognitive model that consists of multiple cognitive modules that have physical representations in the brain. The theory attempts to explain cognitive processes in general. It is also used for producing adaptive tutoring systems in mathematics and science (http://act-r.psy.cmu.edu/).

Adaptive tutor - is a tutoring system that changes "according to student's changing knowledge" and "presents learning objects the student is able to understand" (Albert & Mori, 2001, p. 29).

ALEKS - Assessment and Learning in Knowledge Spaces is an artificial intelligence-based adaptive tutoring system that allows students to progress at their own pace and work only on topics that they do not know. The database for each student includes data related to course topics, times when the student worked in ALEKS and scores on assessments. ALEKS offers courses for a wide variety of academic subjects and is implemented at many schools. The schools can customize courses. Mathematics implementations range from elementary school to college calculus.

Artificial intelligence (AI) – is the ability of computers to emulate human thinking.

Cognitive tutor – is ICAI that adapts the content to the learner based primarily on the learner's cognitive processes.

College placement test – test that students take upon enrolling into the college in order to measure their mathematics and language skills. Based on scores in mathematics and their major, students are advised to take appropriate mathematics courses.

Emporium-style course – is a course where students work independently in an online environment but they also have an instructor available to answer their questions while they work at school.

Computer-assisted instruction (CAI) – is instruction delivered by computers.

Expert system – is a system that contains "a lot of expertise on a particular domain" (Camstra, 2008, p. 301) but is generally not intended for education, which means that there is no curriculum and there are no educational strategies. The user is only interpreting results.

Intelligent computer-assisted instruction (ICAI) – is CAI that can adapt the instruction to the individual learner and can present complex content in a meaningful way using multiple paths.

Intelligent tutor – is ICAI that adapts the content to the learner based primarily on the content structure.

IBM SPSS (Statistical Package for the Social Sciences) – is a software that is used to process the data statistically.

KST (Knowledge Space Theory) - is the theory that explains how complex educational content can be represented efficiently so that the learners' knowledge can be assessed quickly and with high accuracy. Falmagne, Doignon, Koppen, Villano and Johannesen (1990) define knowledge space as a family of all knowledge states and knowledge state as a subset of questions and problems. ALEKS is based upon KST.

Member check – is "an opportunity for members (participants) to check (approve) particular aspects of the interpretation of the data they provided" (Carlson, 2010, p. 1105). The participants can be given either transcripts, or themes and patterns that emerged. A member check can be done individually or in group setting. It can be done as many times as the research requires.

Remedial/developmental course – is a "coursework offered at a postsecondary institution (either community college or four-year) that is below college-level work. It is also known as "developmental education," "basic-skills training," or "nontraditional coursework.’”’ (Education Commission of the States, 2012, para 1). In the case of this study four Basic Algebra courses fall into this category (Basic Algebra I to IV). Basic Algebra I and II do not count towards a college degree.

CHAPTER II

REVIEW OF THE LITERATURE

Mathematics Education and Technology

The importance of technology in mathematics education is recognized by all major organizations including the National Council of Teachers of Mathematics (NCTM), Mathematical Association of America (MAA), and American Mathematical Association of Two-Year Colleges (AMATYC). Technology was one of six principles cited in “Principles for School Mathematics” by NCTM (2000, The Technology Principle, para. 1): “Calculators and computers are reshaping the mathematical landscape, and school mathematics should reflect those changes. Students can learn more mathematics more deeply with the appropriate and responsible use of technology.” By 2011, the NCTM position on technology in mathematics education became even more explicit: “It is essential that teachers and students have regular access to technologies that support and advance mathematical sense making, reasoning, problem solving, and communication” (para. 1). MAA’s Guidelines for Programs and Departments in Undergraduate Mathematical Sciences, under Curriculum and Teaching, acknowledged the impact of technology and the need to “adjust the curriculum to reflect the expanded use of technology in each discipline and in the workplace” (MAA, 2003, p. 10) as well as to enhance student learning, communication, and teacher professional development by the use of technology. The AMATYC’s Strategic Plan (2012) emphasized the use of emerging technologies in the college curricula, and in the professional development of faculty and research on student learning.

The road to the current position where technology is recognized as an essential factor in education was not straight. In the early 1960s two very different instructional approaches competed for the attention of U.S. policy makers. Skinner (1964) was supportive of instructional machines that could teach individual students. He predicted that in 20 years some of the teachers' time would be freed by the use of these machines, and that teachers would be able to provide individual instruction to students, as was the case in the past prior to mass education. Twenty-two years later, Skinner (1986) gave his account of what happened in the meantime. The term *programmed instruction* was introduced and that term indicated the use of more complex teaching machines and computers in instruction. The teaching results were positive but "the educational establishment was not impressed" (Skinner, 1986, p. 105) for a number of reasons, including extra costs, retraining of teachers, and disruption of the "phalanx system" in classrooms (Skinner, 1986, p. 105). In addition, Skinner felt that the principles of programmed instruction were misinterpreted and the results underappreciated. Instead of building on programmed instruction and extending the existing educational system, the policy makers in the 1960s embraced a constructivist approach to teaching expecting great advances in U. S. education. Bruner's "The Process of Education" (1960) was a pivotal document that was widely accepted and fueled educational change in the United States. A decade later Bruner (1971) acknowledged that the movement was overly idealistic and unprepared for the realities of the huge education reform that it initiated and could not control. A number of ideas that later proved incorrect were initially taken for granted. Some examples of these incorrect ideas are the idea that a child at any age can be taught any topic, that students are motivated to learn all the time, and that learning by doing is by far a superior teaching method. Exploration and collaboration, instead of direct instruction, were viewed as a way of gaining student interest and promoting deep learning. Direct individual instruction using computers was viewed as limiting and producing bad results (Erlwanger, 1973). Constructivism later took an even more radical form (von Glasersfeld, 1990) and continues to be a major force in education to this day. Social aspects of learning also became major players in education (Bandura, 1989), and when computers and the Internet changed the educational environment, collaborative learning was one of the first instructional strategies to benefit from the technological revolution and use of the Internet. Eventually, individual instruction using computers became a focus of educational research and practice. What Skinner predicted came to be true several decades later and now sophisticated systems that teach individual students and satisfy requirements of modern learning are here to stay.

The pedagogical approaches that were so sharply polarized in the past now tend to blend indicating that there is no single best way to support learning. Technology certainly offers a variety of implementation options and this variety is reflected in a wide array of educational software. Simple drill-and-practice programs such as Best Times Table (http://besttimestable.com/) have existed for a long time now. These types of programs relate to the lower levels of Bloom's revised taxonomy (remembering, understanding, and applying). Programs that support higher levels of learning (analyzing, evaluating, and creating) require more complex technology and as a result have been developed at a slower pace. Although there is a need for drill-and-practice in mathematics to help students learn basic facts and symbols, mathematics is primarily about problem solving and critical thinking. It is essential to understand the learner's cognitive processes in order to develop software that will effectively teach these skills. In the layered model of the brain (LRMB) by Wang and Chiew (2008, p. 90) presented in the Figure 1, we see that problem-solving processes interact with almost all other cognitive processes. Memory (layer 2) consists of Sensory Buffer Memory (SBM), Short-term Memory (STM), Long- term Memory (LTM), Action-buffer Memory (ABM), and Conscious and Perception Memory (CPM) (Wang & Chiew, 2008, Wang, 2009). The model shows the complexity of connections between cognitive processes, and this in turn indicates the complexity of modeling cognitive processes in the educational software. Teachers can attempt to influence some of the cognitive processes of their students by planning educational activities ahead of time, but many decisions are made during classroom instruction and are based on a teacher's experience as well as human nature. Quality educational software also must deal adequately with the same complexity.

In many cases educational software is intended to be used as a teaching tool - the teacher determines when and how it will be used in the classroom. In such cases the software must have features that make it worthwhile for the instruction, but the teacher is still in control of the majority of decisions that influence student learning.

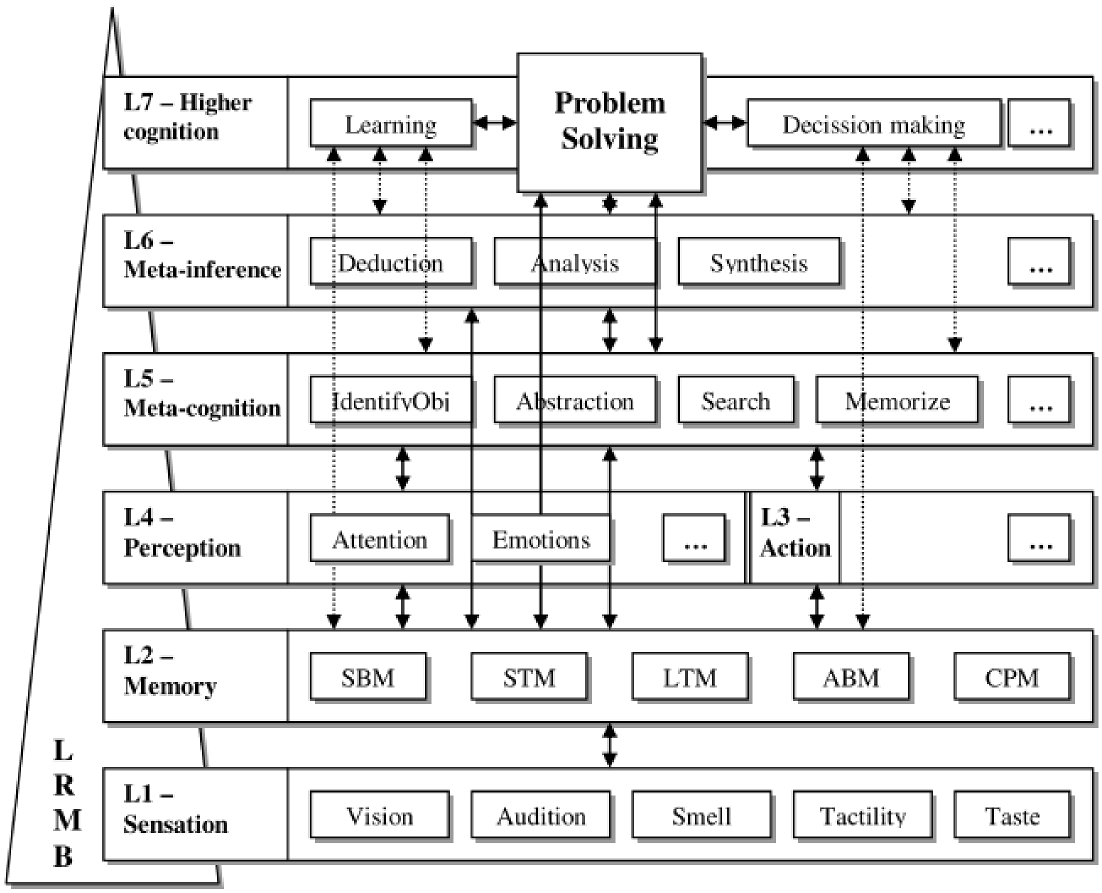


Figure 1. Interaction between problem solving and other cognitive processes in LRMB.

For example, a tool may help the teacher demonstrate a mathematical concept in visual ways that are hard to achieve otherwise. An examples of visual presentations enabled by technology are The Geometer's Sketchpad (Bowers & Stephens, 2011), and

AlgebraArrows (Doorman, Drijvers, Gravemeijer, Boon, & Reed, 2012). Technology tools can help students problem solve by providing visual representations; one example is Fish Farm (Lee & Hollebrands, 2006). In these cases the teacher typically introduced the tool to the students and helped them to use it, meaning that the teacher maintained control of the overall learning process.

Software also can facilitate student communication and reflection. Peer-tutoring systems (Tsuei, 2012), blogs (Nehme, 2011), and chats and forums (Cooper, 2012), all had a positive effect as long as they were used in a meaningful way in class. Chen, Chiu, and Wang (2012) found that asynchronous online discussions were superior to face-to-face discussions because students had more time for reflection and learning before they communicated their ideas. In technology-supported communication, a teacher's presence and guidance is valuable because software by itself may not provide the same level of guidance and feedback.

The importance of feedback in education is widely accepted. Economides, (2006) offered a fairly general definition of feedback in education:

> Feedback is the educator's (real or artificial) response to the learner's actions, thoughts, emotions, needs, attitudes, wills, intentions etc. It may aim to control, guide and regulate the learner, or instruct and teach her, or help and support her. It may inform the learner about her progress, her strengths and weaknesses. It may also try to develop, enhance and improve the learner's strengths as well as reduce and correct her weaknesses. (p.15)

This definition reflects the complexity of the learning process and the many ways it can be affected through feedback. The definition can be extended by including peer feedback that is often present in online systems. In essence, the definition ties together intellectual, motivational, and emotional aspects of thinking as suggested by Vygotsky (as cited Shute, 2008, p.177).

The choice of feedback type is often dictated by audience, content, and technology. Feedback options had many forms in the past, but with the development of technology the number of options increased significantly. Veloski, Boex, Grasberger, Evans, and Wolfson (2006) found that in the case of physicians, prolonged feedback provided by a credible source such as professional groups or hospital administrators had the best results. Moreno (2004) investigated the effect of explanatory feedback versus corrective feedback on novice learners in a discovery-based multimedia environment and found that explanatory feedback reduced cognitive overload resulting in better learning outcomes. Narciss and Huth (2006) compared strategic information for error correction (bug-related tutoring feedback) to providing a correct response or providing only the knowledge of a result. In their study, bug-related tutoring feedback resulted in higher achievement and motivation. An extensive literature review done by Shute (2008) focused on task-level feedback that "typically provides more specific and timely (often real-time) information to the student about a particular response to a problem or task, compared to summary feedback, and may additionally take into account the student's current understanding and ability level." (Shute, 2008, p.155). Summary feedback in

Shute's study was defined as the teacher's feedback to the class or to themselves for improving instruction. In the majority of studies included in the review feedback had a positive effect, but in some studies that was not the case. According to Shute (2008, p.177), one possible reason for a negative effect from feedback could be "differences among motivational prerequisites (e.g., intrinsic motivation, beliefs, need for academic achievement, academic self-efficacy, and metacognitive skills)." This observation reaffirms that feedback needs to address learner's actions, thoughts, emotions, attitudes, and intentions, as it was indicated in the definition by Economides (2006). In short, feedback must keep the learner motivated and engaged. Experienced instructors that know their students well can be very effective in their feedback but there is a limitation: they cannot provide personalized feedback to multiple students simultaneously. Software can provide immediate feedback to all students at the same time but the feedback can be personalized only as much as the software is capable of. Immediacy of feedback in the great majority of cases had a positive and motivational effect (Tsui, 2012) so it is the personalization that is the main challenge for any software. Software that provides feedback closer to the feedback from a human instructor is more likely to be effective for the motivational and emotional aspects of thinking.

The introduction of software into the classroom can have benefits but it also may create unforeseen problems. Doorman et al. (2012) and Lee and Hollebrands (2006) indicated that software shortcomings may include tool-imposed limitations, unintended uses, or software bugs and oversights in the design. Teachers, themselves, can cause problems if they are inappropriately using the tool. These kinds of problems usually occur due to lack of training and/or lack of professional development. Teachers must be trained and knowledgeable not only in content but in pedagogy and technology as well (Bowers & Stephens, 2011). Continuous learning requires considerable effort on the part of teachers; because of this effort, teachers need to be taught not only how to implement technology well, but also why the use of technology is so important (Raines & Clark, 2011; Cooper, 2012).

Although the use of technology has both positive and negative aspects, in the future technology will most likely be used even more than it is now. Not only are leading educational groups demanding the use of technology in education, but everyday life requires the use of technology more and more. Students need to learn technology early as well as how to adapt to frequent technological changes. We have already passed several different software implementation stages that were triggered by major technological advances.

As previously indicated, early educational software was used primarily as a supplemental tool with few provisions for an individual learner. Even when some flexibility was added, this flexibility was typically very limited and hard-coded. Such software is called computer-assisted instruction (CAI).

As technology evolved, more powerful computers and software came into existence. It became possible to develop programs to emulate theories that model student cognitive processes, knowledge, and behaviors. The next generation of educational software went beyond the role of being a tool for learning and became actively involved in dealing with students in a similar manner that teachers do. CAIs started incorporating more complex modules that were able to adapt content to the individual learner. Eventually this approach was defined as intelligent computer-assisted instruction (ICAI). In other words the "intelligent" in ICAI means that the software helps each individual learner according to his or her individual characteristics. Although ICAIs may look like ordinary software to a user, they include different levels of intelligence about the learner and the content. The modules that manage the interaction between the learner and content presentation are often based on artificial intelligence (AI) approaches.

According to Camstra (2008), the development of ICAI was inspired by shortcomings of CAI, namely:

- a teaching strategy is built into the program that did not allow for flexibility
- a teaching strategy is intertwined with content making the software development expensive
- individual differences between students are not addressed.

The definition that the author offered is "ICAI programs are complex computer programs that in purpose and external behavior resemble conventional CAI programs, while in internal structure and function they resemble AI programs" (Camstra, 2008, p. 298).

The main features of ICAI often include a structured knowledge base of educational content, teaching strategies in the form of rules that operate in conjunction with the knowledge base, a student model that contains the learner's current state of knowledge, and a user interface. Camstra (2008) differentiated between the “inside” and “outside” intelligence of these programs. The “inside” intelligence is related to the content presentation while the “outside” intelligence is related to the communication to the learner. For example, ICAI programs may look intelligent to the learner despite relatively simple insides because the program knows a lot about the learner and communicates appropriately. On the other hand, if the program with significant “inside” intelligence has less fine-tuned communication to the learner, it may look less intelligent. The intelligence also may have a wide spectrum of values as opposed to a common dichotomy approach (intelligent or not intelligent). This wide spectrum of levels of intelligence resulted from different programming implementations. For example, ICAI could be built from scratch, it could be upgraded from CAI, it could be proto-typed, or it could be based on expert systems.

Although the ICAI concept looks very promising, ICAI programs are often domain-specific, expensive to develop, and rarely available as commercial products. In order to be commercially successful they must take general approaches when addressing content and learner complexity. So far two general approaches have been successful: one focuses on the rules that organize the content according to dependencies within it, while the second approach focuses on the cognitive processes of the learner.

When ICAIs focus primarily on dependencies between content topics, they are called intelligent tutors. The rules that present the content in intelligent tutors are the same for all learners although the learner's current knowledge state also plays a role in how the instruction is presented.

When ICAI systems put learner cognitive processes first, then the content is presented based on what the system assumes the learner is thinking. Such systems are called adaptive or cognitive tutors.

The difference between intelligent and adaptive tutors is not clear cut – it is more based on the prevalent method that is implemented in the specific software. It may be the case that in the future different approaches to computer tutoring will merge and become part of a larger multifaceted system of artificial intelligence.

Many other names for ICAIs exist in the research literature in addition to intelligent and adaptive tutors. Some examples are intelligent tutoring systems, adaptive tutoring systems, computer-based adaptive learning environments, and intelligent language tutoring system. Despite different names they all have the same goal – to present a complex content to an individual learner using technology.

ICAIs: Intelligent and Adaptive Tutors and the Theories Behind Them

As opposed to computer-assisted instruction (CAI) that typically presents instructional content in the same way to all learners, intelligent computer-assisted instruction (ICAI), adapts content to the learners' needs. ICAIs monitor and evaluate student knowledge. Based on these evaluations, ICAIs guide student learning. This monitoring is "comparable to the teaching behaviour of a private teacher, taking his or her knowledge about the student and the results of learning science into account" (Albert

& Mori, 2001, p. 24). As mentioned in Camstra (2008), the design of intelligent tutors often depends heavily on the educational content. We'll first review two examples of dealing with the complexity of content.

Amaral, Meurers, and Ziai (2011) investigated a way to incorporate Intelligent Language Tutoring System (ILTS) into Foreign Language Teaching (FLT). ILTSs typically provide feedback to the user based on errors made or by highlighting what was done well. Sequencing of the instruction often can be adjusted for the individual learner as well. When errors and good answers are hard-coded, this limits the content that can be covered because the number of possible errors and good answers grows exponentially as the content grows. That is why for a more comprehensive ILTSs, language analysis and feedback must be based on algorithms researched in Natural Language Processing (NLP). Meurers (2012) described NLP as the intersection between linguistics, computer science, and psychology. NLP modules are typically created for a specific activity type. For example, a spell checker may be used for simple fill-in-the-blank exercises. More complex exercises that check language forms or require semantic analysis and inferences often require multiple NLP modules. In such cases activity types and error taxonomies are used to determine which NLP modules should be engaged. The question of why all NLP modules are not used in every analysis is answered by the principle "don't guess what you know" (Amaral, et al., 2011, p. 7). In other words, hard-coded answers are acceptable in some cases while more complex activities may require more complex processing, but the goal is to always use the simplest possible approach. In cases when more than one NLP module must be used to determine the correctness of the answer, NLP modules can add annotations thus increasing the information (annotation-based architecture).

Annotations are done as a part of a dynamic process in the ITLS system TAGARELA (http://purl.org/icall/tagarela) described in Amaral, et al. (2011). This dynamic process is called a NLP pipeline. The authors argued that annotations could be built into the central repository rather than added dynamically by separate NLP modules. The central repository would be based on an Unstructured Information Management Architecture (UIMA) framework developed by Ferucci and Lally in 2004.

Although UIMA may simplify data structures in the system, overall complexity of the system would increase because the authors proposed that information about the performed activity and the specific learner needed to be added to the analysis. Information about performed activity could be provided by different levels of analysis from hard-coded values to activity-unrelated NLP modules. An example of an activity-unrelated NLP module is the feedback on free-form essays. Information about the learner's typical language use, errors, and strategies could be collected over time and used when disambiguating the learner input. Once an error was classified, the system would provide feedback by the Feedback Manager.

The study of Amaral et al. (2011) showed the dynamic nature of the development of intelligent tutors. Not all functions are developed at the same time and to the same depth. At the moment when the study was written, language tutor TAGARELA had quite a lot of “inside” intelligence (Camstra, 2008) because it was capable of parsing many user inputs. Because student information was not processed at all, the program could be perceived as “unintelligent,” or with little “outside” intelligence. For example, if the student wrote one word many times correctly and then made a typo, the system would most likely classify the error as a “mistake” rather than a “typo.” The student would on the other hand expect the system to realize that this was a typo and may view the system as “unintelligent.” In fact, the inability to distinguish between a typo and lack of knowledge does indicate a shortcoming of the software. Because TAGARELA was mainly focused on the rules related to the content, the system could be classified as an intelligent tutor (with a non-existent learner module).

Another example of ICAI focused on dependency rules for the content is Assessment and Learning in Knowledge Spaces (ALEKS). The theory behind ALEKS is a Knowledge Space Theory (KST). Falmagne et al. (1990) defined knowledge space as a family of knowledge states, and knowledge state as a subset of questions and problems. Figure 2 from Falmagne, Cosyn, Doignon, and Thiery (2003, p. 7) represents problem types in several mathematics courses and the dependency links between them. Each of the 397 points represents a problem type.

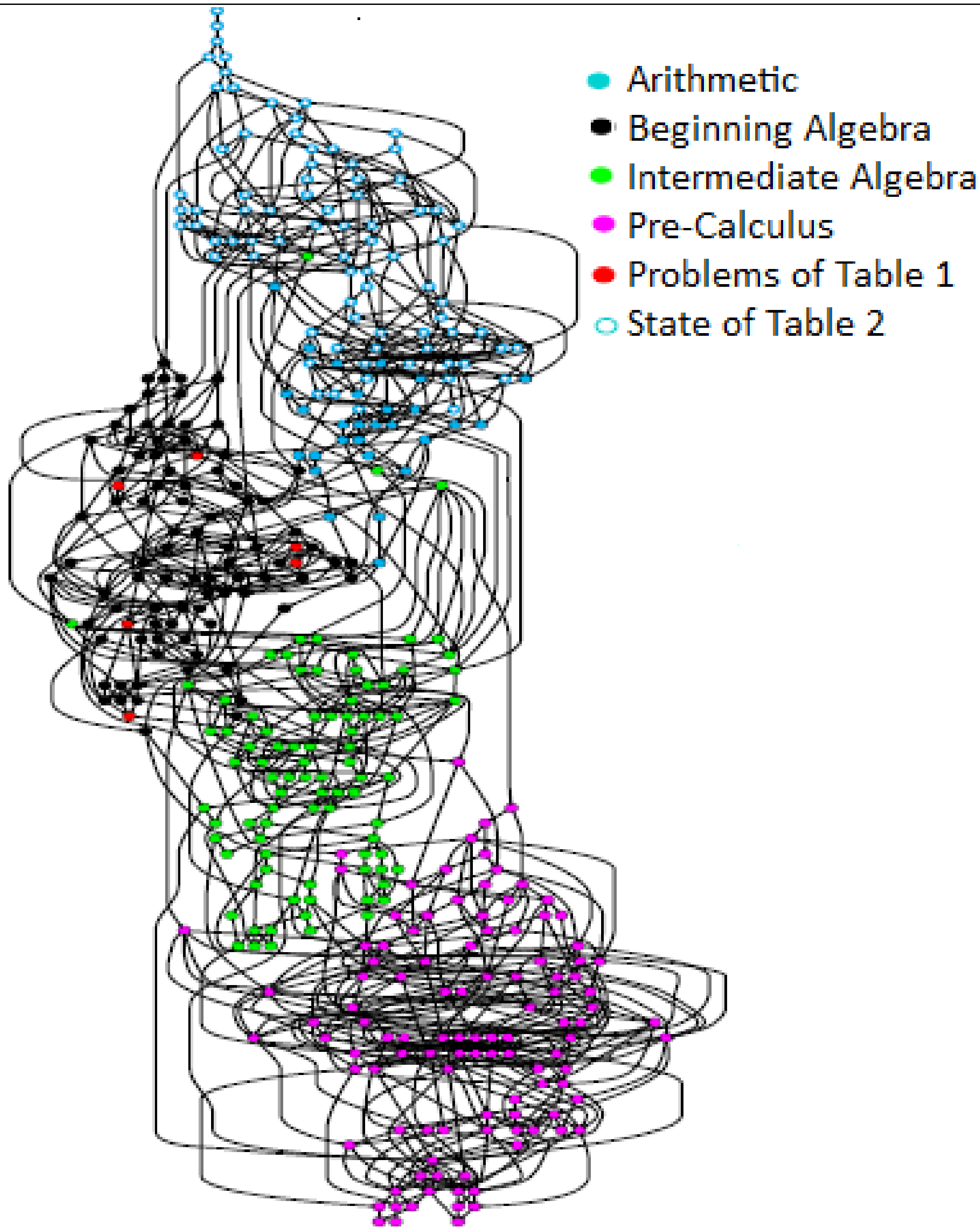


Figure 2. Combined precedence diagram for Arithmetic, Middle School Algebra, and Pre-Calculus.

The task of building a knowledge space consists of two steps. The first step is to take input from an expert teacher about possible problem types and their dependencies. The second step involves the refinement of the knowledge space through the statistical analysis of a large number of student assessments. As the knowledge space is refined, the number of nodes is reduced allowing faster assessment of knowledge (Falmagne et al., 1990). The reduction of nodes is based on Stochastic Learning Theory where model simplification is achieved in steps. In each step the currently used model is replaced by a simpler one if no statistical difference in performance is found. The model has the student age as a variable so it is robust with respect to age, and this means that students of different ages may have different learning paths. The knowledge space represents an ideal path for a student when other factors are not considered, but careless errors, lucky guesses, and the changing knowledge states of the learner must be accounted for as well. These factors can be viewed as "noisy data" and they are handled through Markov decision process where the transition from one knowledge state into another is affected by the student's past performance (Falmagne et al., 1990). The ultimate goal is accurate and efficient assessment of the individual learner.

In conclusion, KST has two major parts. On one side there is a knowledge space that consists of subsets of problems or questions. These subsets represent knowledge states that learners can be in without guessing, making careless errors, or due to other factors such as response latency and multiple responses. On the other side, guessing, careless errors, and other factors are handled by different approaches (for example

Markov procedures). The use of multiple mathematical models shows that the task of creating individualized tutoring system is complex and became possible only after the huge technology developments of recent years. New programming tools and powerful computers are the backbone of intelligent tutors. Twenty years after KST was proposed (Falmagne et al. 1990), commercial software based on KST is used by millions of students: ALEKS has commercial intelligent tutors for mathematics, business, and science.

One example of ICAI focused on cognitive processes is a cognitive tutor based on Anderson's Adaptive Control of Thought - Rational (ACT-R) theory. ACT-R models cognitive processes, and it consists of multiple cognitive modules that have physical representations in the brain. In the beginning ACT-R was focused on different modules but as the theory evolved in 2004, Anderson, Bothell, Byrne, Douglass, Lebiere and Qin, showed how four major components of the system (the perceptual-motor modules, the goal module, the declarative module and the procedural system) could contribute to the overall integration of cognition. The organization of information in ACT-R 5.0 is presented in Figure 3 from Anderson et al. (2004, p. 74).

Production rules update the buffers, and there is a mixture of serial and parallel processing. A special programming package developed to model the theory contains commands that represent the cognitive functions described in the model. The programming package is used for brain simulations and also for developing cognitive tutors.

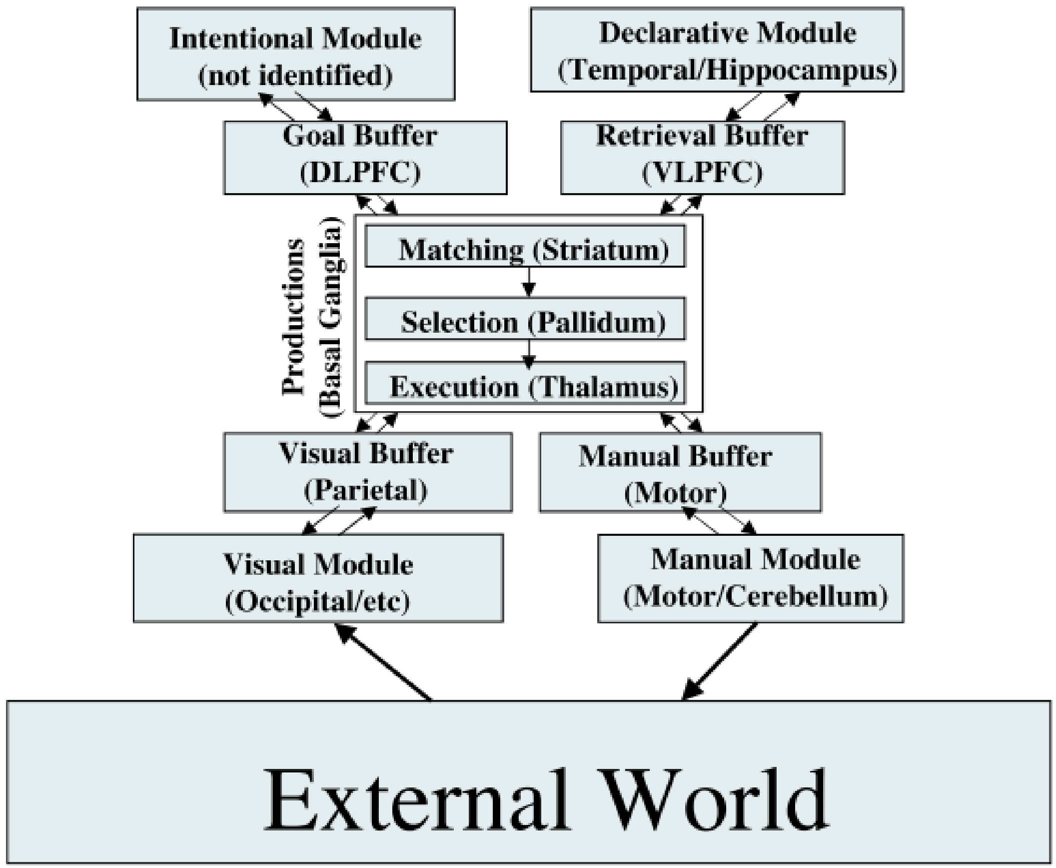


Figure 3. The model of ACT-R 5.0

After ten years of development of cognitive tutors, Anderson, Corbett, Koedinger and Pelletier (1995, p. 202) defined the tutor as “a learning environment in which helpful information can be provided and useful problems can be selected. We are able to take actions that facilitate learning because we possess a cognitive model of where the student is in the task.” These researches also pointed out that outside factors, such as social issues in the classroom and unresolved curriculum issues, may prove to be more important for the success of the tutor than its cognitive fidelity. Koedinger and Corbett (2006) reported that more than 2,000 schools, and over 500,000 students used Cognitive Tutor for algebra which was based on ACT-R theory. In many cases, students spent two days with Cognitive Tutor and three days in the classroom and the results showed 15% higher scores on objective tests when compared to students in a traditional Algebra course. Commercial cognitive tutors based on ACT-R theory are provided by Carnegie Learning, a company founded by cognitive and computer scientists from Carnegie Mellon University in 1998.

The presented intelligent and cognitive tutor examples show that different ICAI systems use different theories as a backbone and are at different stages when addressing individualized student tutoring. KST is a much more limited theory than ACT-R as it does not attempt to address all cognitive processes. At this stage KST is appropriate primarily for well-defined and structured subjects. This limitation does not mean that it cannot grow in the future into new areas of cognition as it tries to address ill-defined topics or enhance its current interface with the more sophisticated interactions with the student. ITLS TAGARELA is so focused on the language complexity and NLP processing that the learner is entirely neglected. On the other hand, perceived cognitive processes of the learner are the focus of tutors that are based on ACT-R theory.

Learner Characteristics

Although some ICAIs do not track learner characteristics the more comprehensive ones do. Amaral et al. (2011) mentioned that learner characteristics needed to be added to TAGARELA ITLS to address some shortcomings such as recognizing typos. KST addressed learner characteristics by predicting what a learner is likely to know based on the learner's current knowledge state and past performances. ACT-R places the learner in the center. We will see here that the research on the learner is quite large and that many different approaches are being proposed.

Vandewaetere, Desmet, and Clarebout (2011) differentiated between adaptive and intelligent instruction. Adaptive instruction is mainly focused on the characteristics of the specific learner while intelligent instruction is primarily rule-based and focused on content. They classified adaptive instruction as follows:

1. Macro-adaptive, based on masterly learning approach (go-at-your-own-pace or based on priorities of tasks).
2. Aptitude-treatment interaction (ATI) approach where pre-test measures such as knowledge, attitudes, and cognitive abilities determine instruction.
3. Micro-adaptive instruction that evaluates student needs within the task and guides on-time instruction for the learner. In this area artificial intelligence (AI) techniques are helpful so Intelligent Tutoring Systems (ITSs) may be examples of micro-adaptive systems.

The framework of adaptive instruction described in Vandewaetere et al. (2011) is similar to the ITSs framework defined by Camstra (2008) earlier in this study but Vandewaetere et al. (2011) decided to view the interface model as a part of the pedagogical model thus reducing the number of models to three: learner, expert, and pedagogical/instructional. The comparison of the frameworks is presented in the Table 1.

Table 1

Comparison of ICAI frameworks by Camstra (2008) and Vandewaetere et al. (2011)

Camstra (2008) Main ICAI features	Vandewaetere et al. (2011) The framework of adaptive instruction
Student model that contains learner's current state of knowledge	Learner model
Structured knowledge base of educational content	Expert or domain model
Teaching strategies in the form of rules that operate on the knowledge base	Instructional or pedagogical or tutoring model
User interface using natural language	Interface model - a part of pedagogical model

In some ITSs, the framework can be even more simplified. For example, ACT-R theory (Anderson et al., 1995) is an ITS based only on the expert and pedagogical models. The pedagogical model in the ACT-R framework is designed to emulate student cognitive processes and the production rules generated by it guide the learning.

If the student is used to personalize the instruction, then parameter values of that specific student are used to personalize both content and instruction. In this approach, the learner model is the starting point. The content in the learner model can vary in different ITSs and adaptive systems. A literature review by Vandewaetere et al. (2011) was done based on the tripartite framework of adaptive instruction presented in Figure 4 (p. 122). Forty-six journal articles and six excerpts from conference proceedings were reviewed.

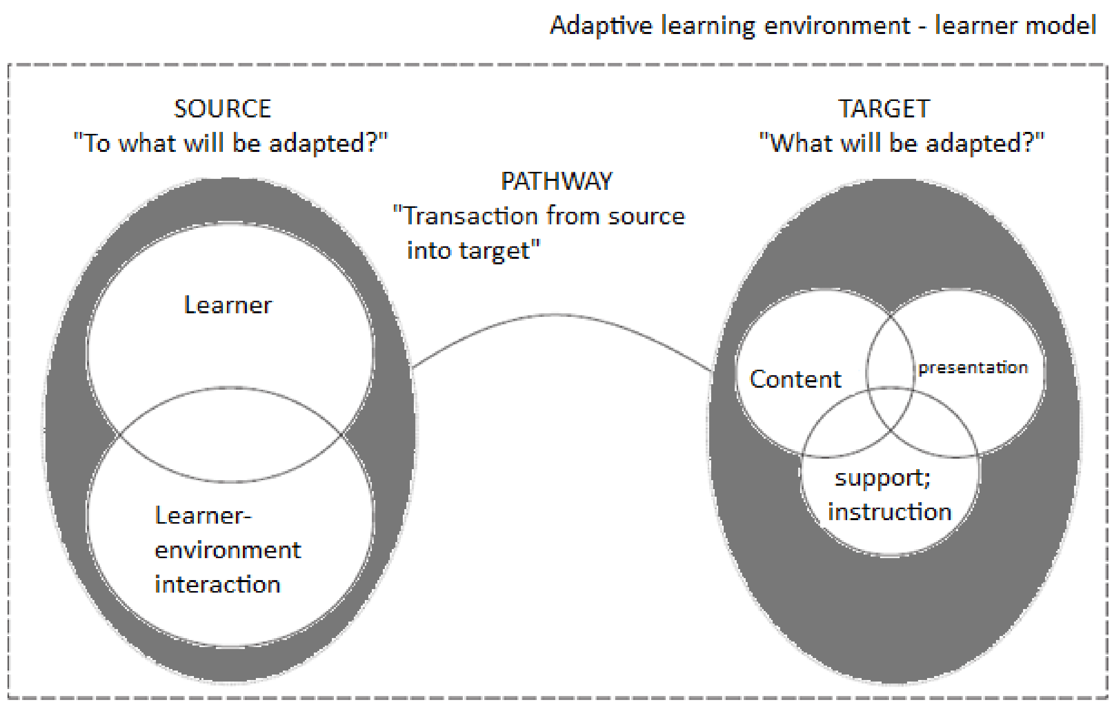


Figure 4. The tripartite structure of adaptive instruction.

The framework of adaptive instruction has three components: the source (the learner or what the instruction will be adapted to), the target (the domain or what will be adapted) and pathways as translations from the source to target (the pedagogical model). The source from the framework of adaptive instruction (Figure 4) was further investigated with the focus on the learner's cognition (working memory capacity, prior knowledge, cognitive style, learning style, and learning goals), affect (certainty, frustration, and confusion), and behavior. Because behavior is based on the learner's cognitive and affective states, it was mainly represented as controls, such as the number of tries per task, or the need for help and feedback.

Most papers discussing one or more learner characteristics are theoretical. In the few experimental studies that exist two approaches were used. One approach, within cognitive tutors, was to represent student knowledge by production rules and then to compare one or more steps taken by the student to the steps in the production system. Another approach, constraint-based modeling, is based on the learning from the performance errors. In both cases the focus is on short-term student activities and the information about the learner that is maintained is most likely very limited.

The target from the framework of adaptive instruction (Figure 4) can be broken into content, accompanying support, and display (presentation). Targets can be classified according to multiple criteria. One criterion is time-related. The target can be static (when long-term, general learner characteristics are taken into account and the adaptation is done before the task), or dynamic (both differences between learners and differences within the learner at different times can be accounted for, which requires run-time adaptation). Another classification is based on control. The adaptation can be controlled by the computer, by the instructor, or by a combination of the two. When the adaptation is controlled by the computer, the learner is often given more freedom. The system typically provides topics that the learner is ready to learn and then the learner selects the topic to work on. The free choice of topics is expected to enhance learner's motivation and self-regulation. The open learner model (OLM) offers even more user control by allowing the user to view, and in some cases, also edit his or her profile. By editing the profile, the user has control over how he or she will be treated by the intelligent tutor.

Pathways from learner to content in Figure 4 represent actions by adaptive or intelligent systems. Adaptive systems mainly focus on user's characteristics while intelligent systems use artificial intelligence (AI) principles to enhance learning. Although the two approaches are similar, and in some areas may even overlap, they can be differentiated. Adaptive systems can use approaches that make the adaptation less fine-grained, for example, clustering students based on certain characteristics.

In some cases learner characteristics are not recorded, but instead sets of triggers are used to adapt the educational environment to the students. This approach is called stereotype modeling as opposed to feature-based modeling where the learner's characteristics are stored and constantly updated. Feature-based modeling is prevalent in a web-based environment. The two approaches also may be combined to address the problem of the "new user" where no profile exists in the beginning. For example, stereotype modeling can be used at the beginning, and later on, feature-based modeling can take over.

Some types of modeling of adaptive systems focus on student misconceptions and errors based on the assumption that as it is important to track what the student knows, it is also important to know what the student does not know. Models that take this approach are called constraint models or bug models.

Intelligent systems were primarily rule-based in the past, but recently a Bayesian network has been used to represent the uncertainty of inferences made about the learner such as beliefs and abilities, or even to deal with missing data. More recently, fuzzy logic has been used to evaluate learners because it deals with imprecision and provides the same type of flexibility that human tutors use when evaluating learners. Fuzzy logic has been combined with neural networks and, in that combination, learner answers could be predicted based on generalizations over similar cases or even new and unknown sequences could be recognized.

The literature review about the learner models by Vandewaetere et al. (2011) showed the wealth of theoretical approaches to learner modeling. These multiple approaches were due to the complexity of the problem of how to individualize the learning and make it most effective. The recommendation was that empirical studies need to be conducted in greater numbers to test each model and its effectiveness in learning, thereby providing information pertinent to further theory development.

Desmarais and Baker (2011) reviewed and analyzed two major types of intelligent learning systems and explained in-depth how knowledge nodes were managed. One type was procedural and included cognitive tutors and constraint-based modeling. The student actions were compared to the rules (correct and buggy-rules). When the student made an error, just-in-time instruction was delivered making the feedback very fine-grained and effective. With each problem the evaluation started anew and typically no long-term student information related to the material covered was kept. This approach is called Model Tracing.

A model of knowledge nodes that is built over time based on a large number of students' assessments is called Knowledge Tracing. It is based on content sequencing where the software attempts to make a broader skill assessment when evaluating student's input. Intelligent tutors with knowledge tracing guide student's learning with the least amount of evaluations and are especially useful when presenting a larger and more complex content. Knowledge tracing supports simultaneous evaluation of multiple skills that are not closely related. Evaluation of student actions is done based on a complex node structure that is, in most cases, constantly being improved and calibrated using assessments of students. In other words, the more the instructional material is used by learners, the better the system becomes in evaluating them. Knowledge-tracing model is also called transfer model.

In recent years, the modeling of meta-cognition, motivation, and affect became increasingly present in the research primarily because unmotivated students are often disengaged and achieve unsatisfactory results. Research related to meta-cognition includes help-seeking, help-avoidance, self-regulated learning, self-assessment, and setting learning goals. Motivation is measured through desire for control, confidence, and independence. Affect covers a wide range of research topics such as anger, happiness, joy, boredom, fear, and frustration. Software that can detect student emotions often combines physical sensors with the analysis of log files. Disengagement is measured through the number of attempts to “game” the system by the student using regularities in the system rather than learning the material. Off-task time is another indicator of disengagement. In some approaches games are used for the prediction of student goals and even development of a complete learner model. All these aspects of learning are essential to improving the student learning experience in intelligent tutors and new findings from the research about learning may eventually be implemented in intelligent tutors.

Open learner models (OLMs) increase model accuracy and learner knowledge about the learning system and, therefore, his/her trust in it. Learner models are assessed based on their ability to predict future student performance or based on external measures such as post-tests of knowledge.

In addition to the modeling of individual learners, group and collaborative learner modeling also exist. Research in group and collaborative learner modeling focuses on team and individual behaviors that promote or hinder learning such as helping, insults, off-topic behaviors, and dynamic groups based on student profiles for in-the-moment tutoring.

Students are typically exposed to many learner models in online environments and in many cases these models overlap. To avoid redundancy, wasted time, and learner boredom, it is important to share information about the learner between different online systems, resulting in a universal learner profile. To achieve interoperability between systems it is necessary to align a set of concepts, their definitions, and the relationships between them. Interoperability is a big challenge for the majority of educational environments today. In addition to standardization issues, problems related to privacy or possible inaccuracies of data in previous systems that may create problems in a current system, are also important to address. Despite of the challenges and difficulties, creating a universal learner profile is a goal worth working for because it may then be used for lifelong learning and will definitely be part of future educational systems.

Potential and Limitations of ICAIs

ICAI in the form of intelligent and cognitive tutors will play a more visible role in education in years to come. They can be used as independent systems or in a combination with traditional lectures. They can address drill and practice (ALEKS – Basic Algebra courses) or can be used for problem solving (Genetic Cognitive Tutor, ALEKS College Algebra course). They can be used in independent study or in group work. ICAIs' ability to adapt to the learner and to evaluate learner knowledge with a minimum of carefully selected questions is valuable for the learner because it is more efficient and engaging.

One limitation is that ICAIs are still expensive to develop and even more expensive to maintain due to continuous upgrades and changes in the technological environments. The cost in itself is a serious limitation but it is even worse when combined with the lack of empirical evidence that these systems are justified. Numerous theoretical studies related to the learner in ICAI environment exist, however empirical studies, as recommended by Vandewaetere et al. (2011), are needed in order to confirm the validity of models and provide evidence to support further theory development.

Another limitation is that ICAIs are not connected to each other. Each system collects information about the learner but that information is not shared. Students must provide the same information in multiple systems and this process becomes inefficient and boring. This limitation is slowly being addressed by the introduction of standards and specifications that future CAIs and ICAIs will need to follow. These standards are in the process of being created and many organizations are currently trying to devise ways to standardize necessary student information in e-learning environments. The three major organizations working on these standards are IMS Global Learning Consortium Inc. (Instructional Management Systems Global Learning Consortium Inc.), the IEEE LTSC (Institute of Electrical and Electronics Engineers, Inc. Learning Technology Standards Committee) and the ISO/IEC (International Standards Organization/International Electrotechnical Commission) (Firesen, 2005).

The IMS Global Learning Consortium Inc. promotes open specifications for establishing interoperability for learning systems. It is comprised of almost 200 government and commercial entities. The IEEE LTSC develops internationally accredited technical standards, recommended practices, and guidelines for learning technology by defining multiple standards related to the architecture, communication, interface, metadata, schema definition, and reusable competency definitions in intelligent tutoring systems. Some of the IEEE standards must be purchased. The ISO/IEC has a sub-committee dedicated to information technology for learning, education, and training (JTC 1/SC 36), also a commercial standard. In addition to these three organizations, standards are affected by AICC (Aviation Industry CBT [Computer Based Training] Committee) and W3C (World Wide Web Consortium). Although the development of standards should be guided primarily by learner needs, political and business influences are very strong. Despite this changing environment that makes software development very challenging, having standards is the only way to ensure long term prosperity. The introduction of these standards is also a part of the emerging Web 3.0 (social-semantic web).

Although the development of some intelligent tutors began around or before the existence of the Internet and Web, the revolution that the Internet and Web introduced affected the development of intelligent tutors. New technologies and tools facilitated complex programming used in intelligent tutors while network connectivity made remote user access ubiquitous. The Web was invented in 1989 by Tim Berners-Lee but in about 15 years, in 2003-2004, huge technological development and changes in Web use warranted a new name: Web 2.0. The initial version of the Web, (some call it Web 1.0 now) primarily gave users the ability to find information and read it. Cormode and Krishnamurthy (2008) point out that the number of content creators in Web 1.0 was small compared to the number of consumers while in Web 2.0 any participant can be a creator. Vast computer resources and new technologies inherent in Web 2.0 allow users to add and share content although this tends to stay within the boundaries of social networks.

Web 2.0 applications such as Facebook, YouTube, RSS feeds, blogs, and user forums, are now part of everyday life. The communication within each Web 2.0 application is so common that users expect it everywhere. If some educational software does not have a common area where students can share the content and communicate, the software looks dated and unattractive. Users also expect to be able to access applications from different devices, another example of how technological development affects the Internet, Web, and all software, including intelligent tutors.

The changed environment of Web 2.0 challenges teachers to learn new applications so that they can lead and engage their students in the emerging online spaces (Greenhow, Robelia, and Hughes, 2009). Commercial intelligent tutors are still boxed in their own spaces but they do incorporate features of Web 2.0 and often offer unique ones. For these reasons, instructors familiar with Web 2.0 trends and interested in the latest technology implementations have a much better chance to effectively use intelligent tutors.

In almost ten years of web growth a huge amount of data has been accumulated. Search engines may be inadequate because they currently return unorganized lumps of data. The barriers that exist between different social networks and applications in general represent an obstacle for any kind of integration. Both of these two problems can be resolved by introducing Web 3.0. In Web 3.0, each piece of data will have metadata to describe its format and meaning. All programs that will operate on Web 3.0 will use metadata to interpret the data and this interpretation will allow free data exchange between applications. Some of the metadata will represent ordinary human meaning and Mika and Greaves (2012) argued that social techniques from Web 2.0 applications, such as tagging, may be used to maintain it.

At this time emerging standards for data related to students and education are created by organizations such as IEEE and ISO/IEC. These standards are actually metadata and are expected to become a part of Web 3.0 environment. Programs that use these standards will be able to freely exchange information and the barriers between different applications will dissolve. Metadata will help with searches as well because the user's profile with its own metadata will be used as a guide. As a result, two students looking for the next step in their education will get different results based on their background and their preferences. Ohler (2008) predicted that the development of Web 3.0 is inevitable but will be much slower than the development of Web 1.0 and 2.0.

Some intelligent tutors already maintain detailed information about students and based on that guide student learning. Student information is not shared, however, so every intelligent tutor must collect this information independently. Standards and Web 3.0 will promote data sharing on everything including the information about users. On one hand sharing information may be very beneficial because intelligent tutors will use existing knowledge about students and be able to build upon it. On the other hand, significant issues about privacy will have to be addressed. In Web 2.0 we already witness problems with privacy in popular applications such as Facebook and YouTube. These problems will only become more pronounced in Web 3.0. The next section illustrates one approach towards creating a high level data structure for education that can become part of the metadata to be used by all students, schools, and anyone interested in reaching people with certain skills.

Future Trends

Today different adaptive systems evaluate the knowledge of the learner in a content specific way and very often use numerical values for the evaluation rather than multidimensional and descriptive values. Sitthisak, Gilbert, and Davis (2007) described a system that will support lifelong learning by keeping the information about every learner in one place. All adaptive systems would then use and maintain that same information. Based on what is known about the learner, the systems would be able to personalize instruction and assessment. The authors proposed a competency-based model for storing the learner's information. Competency is defined as "the integrated application of knowledge, skills, values, experience, contacts, external knowledge resources and tools to solve a problem, to perform an activity, or to handle a situation" (Sitthisak et al. 2007, p. 4). Main characteristics of the model include a rich data structure that can properly represent a competency definition, flexibility to adjust to different learners and their learning goals, and the ability to make real-time updates to the model done through self-discovering functions. Competencies also must be translatable into question statements for the specific subject. The competence model represented below in Figure 5 from Sitthisak et al. (2007, p. 4) uses unified modeling language (UML).

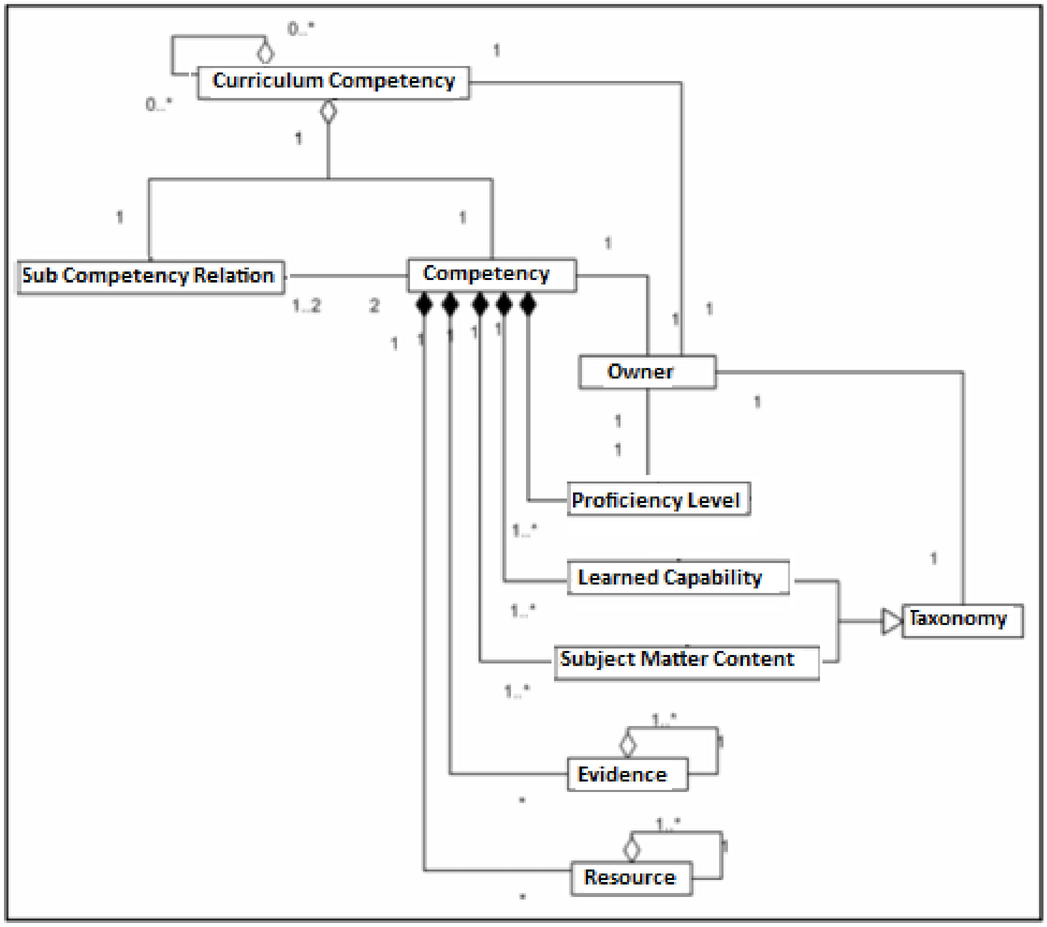


Figure 5. Competency model.

UML models can be transferred into software service artifacts. The services generated are part of the service oriented architecture (SOA), a standard widely accepted in business and industry. The services based on SOA can maintain a student competency model in real-time by using a self-discovery process (services publish themselves in registers that are searchable and that make new services available to the user). In that way each learner will have their competency profile maintained and exposed so that future assessments can be adapted accordingly. Items that students already know will be only lightly checked and the focus of the assessments can be on newly learned items. This idea has been implemented in the Placement Learning and Assessment Toolkit (mPLAT) project funded by the Joint Information Systems Committee (JISC). JISC is a United Kingdom organization that supports innovative use of information and technology in education and education research. The project mPLAT is a step towards a universal artificial intelligence system where a learner will have a comprehensive profile that will be used by different sub-systems that cover different knowledge areas. It is interesting that Sitthisak, et al. (2007) saw the potential of the approach to assessment taken in knowledge space theory (as described in Falmagne et al., 1990). The point that is made in Sitthisak, et al. (2007) is that adaptive assessment should be multidimensional as it is in systems built on KST. KST can even be used to represent competencies as nodes. The initial node structure may be very hard to create but refinements that happen as the model is used would improve it over time.

In the same way as ICAI evolved from CAI, ICAI will be followed by AI. The transitions happen gradually. At first the “intelligence” in CAI was implemented as modest extra features that helped the learner cover the material more efficiently. These simple features eventually grew into the sophisticated modules that strive to address very different problems present in different educational contents and/or to address different learner characteristics. As the modules and their accompanying theories became more complex, a new class of educational software, ICAI, was created. There is plenty of room to further develop and standardize ICAIs but it is never too early to start looking at the next stage which is the integration of different ICAIs into one system. This integration will provide even more comprehensive insight in what the learner knows and what he or she can learn next.

Examples of ALEKS Implementation

ALEKS has been successfully used in multiple mathematics courses and the company maintains a web-page of ALEKS research papers as well as success stories. In this section some ALEKS implementations will be presented including the one that is evaluated in this study.

Hagerty, Smith, and Goodwin (2010) described the use of ALEKS in a college algebra course with the goal of increasing passing rates and subsequent enrollment in higher-level college mathematics courses. ALEKS was used to replace homework sets and was combined with redesigned lectures that presented mathematics theory and application, and included mathematics history. The framework was developed in three phases and produced the desired results: increased student achievement and increased enrollment numbers in higher-level mathematics courses. Goonatilake, Chappa, Bachnak and Miguel (2010) reported the use of ALEKS in a pre-freshmen mathematics summer program that mixed lectures with practice in ALEKS. Jackson and Cossitt (2011) presented a case of using ALEKS as a tool for bringing students ‘up to speed’ in higher-level accounting class without sacrificing class time. Twigg (2011) reported a number of emporium-style course redesigns that both improved student achievement and reduced delivery costs. Although emporium-style course delivery has many flavors, it is mainly characterized by replacing the lecture with on-demand instructor assistance combined with interactive software such are ALEKS, Hawkes Learning Systems, or MyMathLab.

ALEKS has been successfully used in several summer remedial mathematics courses (Tempelaar et al., 2006; Goonatilake et al., 2010). Tempelaar et al. (2006) stated that remedial courses were necessary due to the heterogeneity of students who came from different European Union countries and, also, due to the general inability of students to self-evaluate their skills and readiness for college. Previous remedial programs were mainly regional and had various degrees of success depending on variables such as student motivation and learning environments. Because e-learning eliminates the limitations of time and place, students have more control over achieving the desired level of preparedness for college. The program described in the study delivered a diagnostics test and a free remedial mathematics summer course in a completely online environment using ALEKS. No in-person contact existed between the student and the lecturer or peers. Student questions to the lecturer were mainly related to the course organization and technical issues. There were very few mathematics related questions. The main features of ALEKS were online accessibility 24/7, adaptation to each student, immediate feedback, interactivity, and the school's ability to customize the course content. Only foreign students were invited to participate because they were underprepared for college level courses in the greatest numbers in the past. The effectiveness of the program was evaluated through assessment of students' prior knowledge (diagnostic test), through students' achievements in a subsequent regular course (Quantitative Methods 1), and through the evaluation of students' motivation and completion rates. The diagnostic test was used by 101 students and 55 of them participated afterwards in the optional free summer remedial mathematics course. Twenty-nine passed the summer course while 26 did not. The subsequent college course, Quantitative Methods 1 (QM1) that all students took in the fall consisted of three parts (mathematics, statistics and computer). The analysis of student scores in the QM1 course indicated that students who took the optional free summer course in ALEKS scored better in the mathematics portion than students who did not take the summer course. There was a possibility that more motivated students took the remedial summer course and because of their motivation they also scored better in QM1. To eliminate selection bias related to motivation, scores of the other two parts in QM1 (statistical and computer) were also compared between students who took the remedial summer course and students who did not. The results showed that indeed, students who took the remedial summer course had higher scores in the other two parts as well but the difference was much smaller than in mathematics (the difference in mathematics scores was actually statistically significant). The conclusion was that although motivation plays a role in student scores, some of the score difference in mathematics was due to attendance in summer remedial mathematics course. Because ALEKS was used in QM1 as well, the motivational factor was checked in yet another way by comparing study time between the students who previously took the remedial course and those who did not. The comparison revealed that students who took the remedial summer course studied slightly less than their counterparts who did not take the remedial summer course, thus eliminating the selection bias threat. Although the overall remedial summer course had a positive effect on student achievement in the subsequent course, this effect was not equal between students with various backgrounds. For example, students who had mathematics as part of their major high school program gained less, while students who had math as part of their minor high school program (they had a weaker math background) gained more. Student evaluations of the summer remedial program were mainly positive regardless of their passing rate. In conclusion, the intelligent tutoring system, ALEKS, proved to be an effective method of delivery of the remedial mathematics content in the study. The main limitation of the study was a relatively small number of participants. On the other hand, possible bias issues were addressed and students with various backgrounds were included, supporting generalizations.

Goonatilake et al. (2010) described a one-week-long workshop, Mathematics Enrichment Project (MEP). The project utilized ALEKS in order to prepare minority students for college mathematics. Each day, students first worked in ALEKS for a couple of hours in groups of two or three. In the afternoon, topics of College Algebra were discussed in lecture based format, and in the end students completed an individual assessment each day. Instructors used ALEKS reporting to closely monitor both group and individual progress. Figure 6 from Goonatilake et al. (2010, p. 8) shows daily group progress in a different mathematics topics covered in the workshop. Each topic is represented in different color and darker shades indicate what students knew while lighter colors indicates what students still needed to learn.

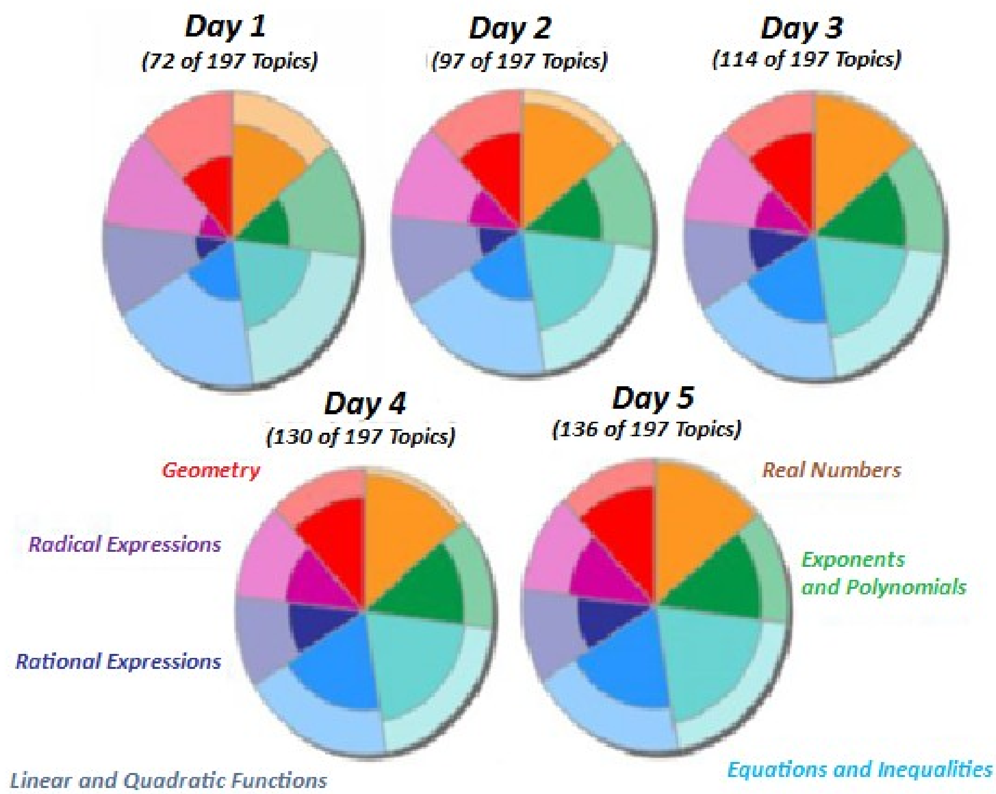


Figure 6. Day-by-day mastery of courses on the basis of topics learned: geometry, radical expressions, rational expressions, linear and quadratic functions, real numbers, exponents and polynomials, and equations and polynomials.

In their evaluations of the workshop, the participants expressed satisfaction with both the organization of the course and ALEKS software. While many students liked the group work performed in the workshop, some mentioned that they would prefer individual work. Goonatilake et al. (2010) also reported grades of Mathematics Enrichment Project

(MEP) participants compared to non-MEP students in the subsequent College Algebra course. The results are presented in Figure 7 from Goonatilake et al. (2010, p. 8) and show that students from MEP had more A's and B's than non-MEP students.

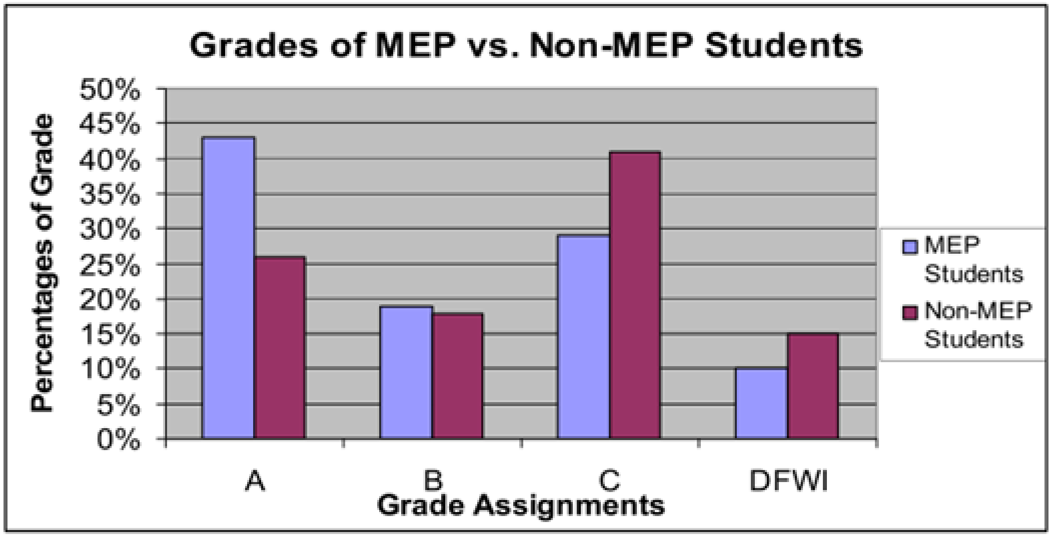


Figure 7. Grade distributions for college algebra courses.

As opposed to Tempelaar et al. (2006) where students worked in ALEKS completely online and there were no lectures or any other imposed structure, Goonatilake et al. (2010) combined ALEKS with group work, lectures, and discussions, and they carefully planned all activities. In both cases ALEKS worked well.

ALEKS Emporium Implementation from this Study

The emporium-style delivery of Basic Algebra courses in ALEKS that is evaluated in this study had the following characteristics:

1. There were four half-semester Basic Algebra courses intended for students who placed into them based on college placement tests. Students could score high enough to place directly into lecture mathematics courses thus skipping Basic Algebra courses.
2. Basic Algebra courses in ALEKS were delivered in emporium style. Emporium style means that there are no lectures but students must spend a certain number of hours in school labs where instructors are available to help. Students may work in ALEKS at home as well.
3. Students worked in ALEKS at their own pace and on problems that they did not know but were ready to learn. ALEKS determined which problems the student was ready to learn.
4. All assessments, including the final examination, were in ALEKS. Progress assessments were scheduled by ALEKS after the student spent a certain amount of time in ALEKS or mastered a certain number of topics. The final examination was scheduled by the instructor and was completed at school. Students had to score 73% or better on the final examination to pass. In addition, students had to achieve a specific percent mastery before the final examination and to complete a specific number of hours in ALEKS.

ALEKS offered immediate feedback in several formats. As students worked on problems and entered their final answers into ALEKS they received immediate feedback in the form of a complete step-by-step solution which, in some cases, linked to the relevant chapters in the e-book. According to Narciss and Huth (2006) complete step-by-step solutions are somewhat less effective than bug-related tutoring where only students' errors are interpreted and reported. ALEKS also offered personalized immediate summative feedback through a student's "pie" and several reports. Students could find out at any time what topics they covered and what was still left to do. They could see how long it took them to complete certain topics and what their scores on progress assessments were. Because ALEKS does not allow students to work on topics that they are not ready to learn, this restriction means that the feedback provided through the student's "pie" did not show topics that student was not ready to learn.

CHAPTER III

METHODOLOGY

Introduction

The goal of this study was to investigate the effect of the intelligent tutor ALEKS, when used in remedial mathematics courses, on success in subsequent college-level mathematics lecture courses. Students in lecture courses who previously took ALEKS courses were compared to students who did not take ALEKS courses on final examination grades and self-reported-preparedness for the lecture course. The study also evaluated students' satisfaction with ALEKS courses and discussed instructors' observations related to students' mathematics knowledge, expectations, and behavior in lecture class.

Research Design

The study used both quantitative and qualitative methods. The design of the quantitative portion was quasi-experimental. Included in the study were students from the selected sections of lecture mathematics courses that immediately follow the Basic Algebra courses delivered in ALEKS emporium. Each lecture course had both former ALEKS students (students who took one or more Basic Algebra courses in ALEKS) and students who did not take Basic Algebra courses in ALEKS. The goal was to compare these two groups of students on final examination scores and self-reported-preparedness for the lecture course. Students' rate of self-reported-preparedness for the lecture course was collected in the student survey.

The student survey, presented in Appendix A, had blocks of questions related to:

- demographics - gender, age, academic standing, the number of courses taken in the current semester, and the number of hours worked at a job per week
- the current lecture course - course name, self-reported-preparedness for the course, and a number of hours of studying per week
- ALEKS – a list of taken remedial courses, the rate of overall learning experience in ALEKS, and three open-ended questions about ALEKS.

Students' demographic information was used in each lecture course to examine whether the two groups of students (former ALEKS students and students who did not take ALEKS courses) were equivalent. Because the courses had different instructors and content, some research questions had to be answered for the individual courses. Quantitative methods were used to answer the following research questions for each of the individual lecture courses:

- Question 1: Is there a difference in final examination scores between former ALEKS students and students who did not take ALEKS courses?
- Question 2: Is there a difference in self-reported-preparedness between former ALEKS students and students who did not take ALEKS courses?
- Question 3: What is the relationship between students' self-reported-preparedness for the lecture mathematics course and the final examination scores for former ALEKS students? What is the nature of the above relationship for students who did not take ALEKS courses?

The following research questions were analyzed for all former ALEKS students:

- Question 2: Is there a difference in self-reported-preparedness between former ALEKS students and students who did not take ALEKS courses?
- Question 4: How do former ALEKS students rate their ALEKS learning experience? The analysis was done with respect to age, gender, and student academic standing.
- Question 5: What is the relationship between the number of ALEKS courses taken and student satisfaction with their ALEKS learning experience?

Qualitative methods were used to analyze open-ended questions about ALEKS from the student survey. The goal was to answer following research questions from the student's perspective:

- Question 6: What do students perceive as effective in ALEKS courses?
- Question 7: What do students perceive as ineffective in ALEKS courses?
- Question 8: How did ALEKS change students' learning and study habits?

The interviews with instructors of lecture courses were analyzed to answer the following research questions from the instructor's point of view:

- Question 9: Where there observable differences in the knowledge between current student groups and groups in the past and, if so, what they were? Did former ALEKS students show some common strengths or weaknesses?
- Question 10: Were there observable differences in students' behavior and expectations between ALEKS and non-ALEKS students? In other words, did

the ALEKS environment affect students so that effects on the current course could be observed?

- Question 11: Were some adjustments necessary in lecture courses because of the former ALEKS students? If so, what and how effective were they?

Sample

Intelligent tutor ALEKS was implemented in four half-semester remedial mathematics courses at the beginning of the academic year 2011 at a large Midwestern university. The four ALEKS courses were Basic Algebra I, II, III, and IV. Successful completion of these courses allows students to enroll in subsequent credit-bearing full semester lecture mathematics courses. Basic Algebra III was the prerequisite for the following lecture mathematics courses:

- Explorations in Modern Mathematics (course code MATH 11008)
- Modeling Algebra (course code MATH 11009)
- Basic Mathematical Concepts I (course code MATH 14001)
- Elementary Probability and Statistics (course code MATH 10041)

Basic Algebra IV was required for one mathematics lecture course:

- Algebra for Calculus (course code MATH 11010)

Only courses that had two sections taught by the same instructor were included in the study. Two sections from the same course were necessary to provide a larger sample per course. The same instructor had to teach both sections of one course so that both sections could be viewed as one group. Purposive sampling was used when selecting courses, instructors, and sections to satisfy these two criteria. Four courses satisfied the criteria and were included in the study. The expected number of student participants was between 120 and 180. The sample sizes for the courses were between 15 and 35 and according to Table C.12 from Hinkle, Wiersma, and Jurs (2003, p. 654), this is sufficient to determine the difference of around 1.25 standard deviations for a two sample case. For the statistics conducted for all courses, a difference of approximately one half of one standard deviation could be detected.

No students younger than 18 were enrolled in any of the courses although, such a possibility existed. All sections had a mix of students who took Basic Algebra courses in ALEKS and students who did not take Basic Algebra courses in ALEKS. Students could skip Basic Algebra courses by scoring well on the college placement test or by transferring in with appropriate mathematics credits from another institution of higher education. Instructors for the selected courses also participated in the study.

The participants in the study were students and instructors from a regional campus of a large Midwestern university where the researcher teaches. The students who took courses included in this study represent the population while students from the selected eight sections were the sample.

Instruments

The instruments for comparing the achievement of former ALEKS students to the achievement of students who did not take ALEKS courses were college placement scores in mathematics and final examination scores in a lecture course. Different college placement tests and procedures have been implemented over time and for that reason the mathematics course that each student was placed into was used to determine the score based on placement. The score based on placement was computed as the arithmetic mean of the minimum and maximum scores for the corresponding mathematics course – the details are in Appendix C.

The same instructor created and graded final examinations for both sections of each course so the two sections were treated as one section. All finals had a maximum of 100 points and required students to show their work. Each course consisted of an ALEKS group (students who took some courses in ALEKS emporium) and a non-ALEKS groups (students who did not take any courses in ALEKS emporium). The gender, age, academic standing, number of courses taken in the current semester, number of hours worked at a job per week, and estimate of study time for the current class per week, from the student survey, were used to describe the student sample and compare the two groups of students in each course.

Former ALEKS students provided a list of ALEKS courses taken by marking them on the student survey. They also rated their ALEKS learning experience. These survey questions were used to determine the relationship between the number of ALEKS courses taken and student satisfaction with ALEKS. Open-ended questions from the student survey about what was effective or not effective in ALEKS courses and how students changed their working habits due to ALEKS were analyzed for possible themes and recommendations for future research and improvements in ALEKS courses.

Interviews with instructors were analyzed for possible themes about knowledge weaknesses or strengths of ALEKS students and changes of student's behavior and expectations. Two interviews were conducted with each instructor. Proposed questions for the guided interviews are in Appendix B. Member checks were done for the interpretive validity. The researcher kept a journal about the steps taken in the research.

Data Collection Procedures

The study was approved by the University's Institutional Review Board. Data included in this study were student scores on the college placement test and the final course examination, student survey results, and interviews and communication with the instructors. Below is the time line for the data collection during the 16-week semester in the fall of 2012:

1. The instructors were contacted by e-mail two weeks before the start of the semester for an informal agreement to participate in the study.
2. The student consent form along with the survey was administered and collected in lecture courses between the third and fifth weeks of the semester. The researcher explained the goal and conditions of the study to students and then distributed the consent form and survey questions. The surveys for each section were sorted by student's last names and then each student was assigned a two-digit sequence number (01, 02,…). A two digit sequence number along with the course code and section number were written on the survey form. These three numbers uniquely identified the student (created a

student ID for this study), and they were used in all data processing eliminating the need to use student names.

3. Students' college placement scores in mathematics were obtained in the sixth week of semester. The scores were hand written on the students' surveys and were entered into the computer at the same time as the other data from the survey.
4. The first interview with each instructor was audio recorded between the third and fifth week of the semester.
5. Mid-term examination scores, the names of students who withdrew from any sections and final examination scores were collected after the semester ended.
6. The second interview with each instructor was conducted after the semester ended.

The researcher was responsible for the collection of all data. Any communication between the researcher and the instructors were considered confidential and were not shared in the form that would reveal identity. The consent forms, student surveys, and recorded instructor interviews will be kept in a secure location and destroyed after four years.

Data Analysis

Quantitative processing was done using IBM SPSS (Statistical Package for the Social Sciences). Qualitative analysis was done by coding responses on open-ended student survey questions and by member-checking of interviews with instructors. Table 2 presents research questions, participants, analyses implemented, and data collected.

Table 2

Type of Participants and Data Analysis for Each Research Question

Research questions	Participants	Type of data analysis	Data collected
1-5	Students	Quantitative	The scores on final examination, rate of ALEKS learning experience, and self-reported-preparedness for the lecture course.
6-8	Students	Qualitative	Open-ended survey questions.
9-11	Instructors	Qualitative	The interviews.

Quantitative Analyses for Each of the Four Courses

The statistical analyses described in this section were done for each course. Two groups existed within each course: former ALEKS students and students who did not take any ALEKS course. When two categorical variables were analyzed, the chi-square test of association was used. When one variable was categorical and another could be considered as continuous, the independent t-test was used. Group equivalency was discussed based on the following fields from the student survey:

a) Gender – by running a chi-square test of association on groups and gender.

b) Age – by running Mann-Whitney U test on groups and age.

c) Academic standing – by running Mann-Whitney U test on groups and academic standing.

d) Number of hours of study per week for this course - by running Mann-Whitney U test on groups and a number of hours of study per week.

e) Number of courses taken in the current semester– by running Mann-Whitney U test on groups and a number of courses taken.

f) Number of hours worked at a job per week – by running an independent t-test with independent variable groups and dependent variable number of hours worked at a job per week.

In cases when normality of scores in the t-test was violated and the ratio of larger to smaller group was greater than 1.5, the Mann-Whitney U test was done instead of t-test. Missing data were excluded.

The analysis of the final examination scores was first done by running ANCOVA with the mathematics score on college placement test as the covariate, groups as the independent variable, and final examination scores as the dependent variable. Because the regression slopes of the covariate and independent variable were different, that is the homogeneity of regression slopes was violated, ANCOVA was replaced with the independent t-test. As a consequence, mathematics scores on college placement tests that have been collected and coded have not been used.

Descriptive statistics were provided for self-reported-preparedness for both ALEKS and non-ALEKS groups. Self-reported-preparedness (dependent variable) was analyzed using a Mann-Whitney U test with the groups.

The relationship between self-reported-preparedness and final examination scores for former ALEKS students was analyzed by the Spearman's Rank Order Correlation. The same was done for the students who did not take any ALEKS courses.

Quantitative Analyses for all Courses

The following analyses were done for all former ALEKS students regardless of the lecture course that they were taking.

The relationship between the rating of ALEKS learning experience and age was measured by a Spearman's Rank Order Correlation. The relationship between the rating of ALEKS learning experience and gender was measured by a Mann-Whitney U test. The relationship between the rating of ALEKS learning experience and academic standing was measured by a Spearman's Rank Order Correlation.

The relationship between the rating of ALEKS learning experience and the number of ALEKS courses taken was analyzed by a Spearman's Rank Order Correlation.

Qualitative Analysis

The part of the research that was qualitative (open-ended student-survey questions and interviews with instructors) was susceptible to interpretation. Students' responses to open-ended survey questions were reviewed by the researcher and one reviewer. The researcher reviewed the responses first and came up with a list of themes and codes for them (see Appendix D). The reviewer coded the responses using the codes. In the end, both researcher and reviewer discussed the coding differences and reached consensus. Coded student responses were reported using frequencies.

The researcher conducted two interviews with each instructor. The first interview was between the third and fifth weeks of the semester and the second was after the semester ended. The instructors were asked to communicate any observations related to student achievement and behavior during the semester but nothing specific was reported. The interviews with instructors included a member check – the researcher restated main points during the interview so that the interviewee could confirm or clarify them. For the second interview, the researcher also sent interview notes to instructors for their confirmation.

CHAPTER IV

RESULTS

Introduction

The main goal of this study was to investigate the effect of the implementation of an intelligent tutor in remedial mathematics course on success in subsequent lecture mathematics courses. This goal was investigated through the analysis of students' grades in lecture courses, students' responses on the survey, and interviews with instructors in the lecture courses.

To answer eleven research questions, both quantitative and qualitative methods have been used. Research questions that required quantitative analysis of final examination scores or self-reported-preparedness have been answered for each of the four courses. In quantitative analyses when students rated their ALEKS learning experience, the processing was done for all students regardless of the lecture course they were taking.

The first interview with instructors established that all instructors had between ten and thirty years of college teaching. They all taught the same course the previous year, so they could compare previous student groups with the current ones. All instructors also were exposed to ALEKS: three taught ALEKS courses while one observed students as they worked in ALEKS. The instructors that taught ALEKS observed that ALEKS was very good at assessing what students knew and what they needed to learn and that it was a very good drill-and-practice tool with good online content.

Number and Type of Participants for Each Research Question

Research questions differed in the number and type of included participants. The total number of students who agreed to participate in the study and took the survey was 130. Out of 130 students, 47 took some ALEKS courses in the past while 83 students never had any ALEKS courses. Research questions 1 and 3 required scores on the final, but because some students withdrew from the lecture course or did not take the final, the number of participants in research questions 1 and 3 dropped to 114. Table 3 presents the number of participants for each research question.

Table 3

The Number and Type of Participants Included in Each Research Question

Research question	Number of participants	Type of participants
Question 1	114	Students who completed the survey and also a final.
Question 2	130	Students who completed the survey.
Question 3	114	Students who completed the survey and also a final.
Questions 4 to 8	47	Former ALEKS students who completed the survey.
Questions 9 to 11	4	Instructors who taught lecture courses.

The Group Equivalency for the Research Questions 1, 2, and 3

For research questions 1, 2, and 3, the two groups of students (ALEKS and non-ALEKS groups) were compared on six variables: gender, age, academic standing, hours of study per week, number of courses taken, and hours of work per week. Research question 2 is related to the student survey that was done at the beginning of the semester so all 130 students who completed the survey were included. The students were grouped according to their lecture course and then, within each course, former ALEKS students and students who never took ALEKS were compared on the six variables.

For each of the four courses no statistical differences were found between ALEKS and non-ALEKS groups on gender, age, academic standing, hours of study per week, and hours of work per week. There was only one statistical difference found for the variable "number of taken courses this semester" in the course Basic Mathematical Concepts. A Mann-Whitney U test indicated that there was a difference between ALEKS ($n = 11$, $M = 19.45$) and non-ALEKS ($n = 19$, $M = 13.24$) groups on the "number of courses taken" ($U = 61.500$, $p = .049$). Eleven ALEKS students had on average 4.82 courses ($SD = 0.982$) while 19 non-ALEKS students had on average 4.00 courses ($SD = 1.054$). This means that in the Basic Mathematical Concepts course, former ALEKS students took a slightly heavier course load compared to students who never took any ALEKS courses. In the other three courses, no statistical differences were found related to the "number of taken courses this semester" variable. Research question 2 was answered for all students as well so the group equivalency has been tested for all students and no statistical differences have been found between ALEKS and non-ALEKS groups.

Research questions 1 and 3 required the score on the final so students who withdrew or did not take a final had to be excluded from the original 130 students resulting in the sample of 114 students. The students were grouped according to their lecture course and then within each course ALEKS and non-ALEKS groups were compared on the six variables. For each of the four courses, no statistical differences were found between the groups on gender, age, academic standing, hours of study per week, and hours of work per week. There was only one statistical difference found for the variable "number of taken courses this semester" in the course Basic Mathematical Concepts. A Mann-Whitney U test indicated that there was a difference between ALEKS ($n = 10$, $M = 19.45$) and non-ALEKS ($n = 19$, $M = 12.66$) groups on the "number of taken courses this semester" ($U = 50.500$, $p = .030$). Ten ALEKS students had on average 4.90 courses ($SD = 0.994$) while 19 non-ALEKS students had on average 4.00 courses ($SD = 1.054$). This result means that in the Basic Mathematical Concepts course, former ALEKS students took slightly heavier course loads compared to students who never took any ALEKS courses. In the other three courses no statistical difference was found related to the "number of taken courses this semester" variable. The results of all tests are presented in Appendix E.

Student Sample

The student sample consisted of 130 students in four courses. There were 39 males and 92 females and their participation in the four surveyed courses is presented in the Figure 8 below.

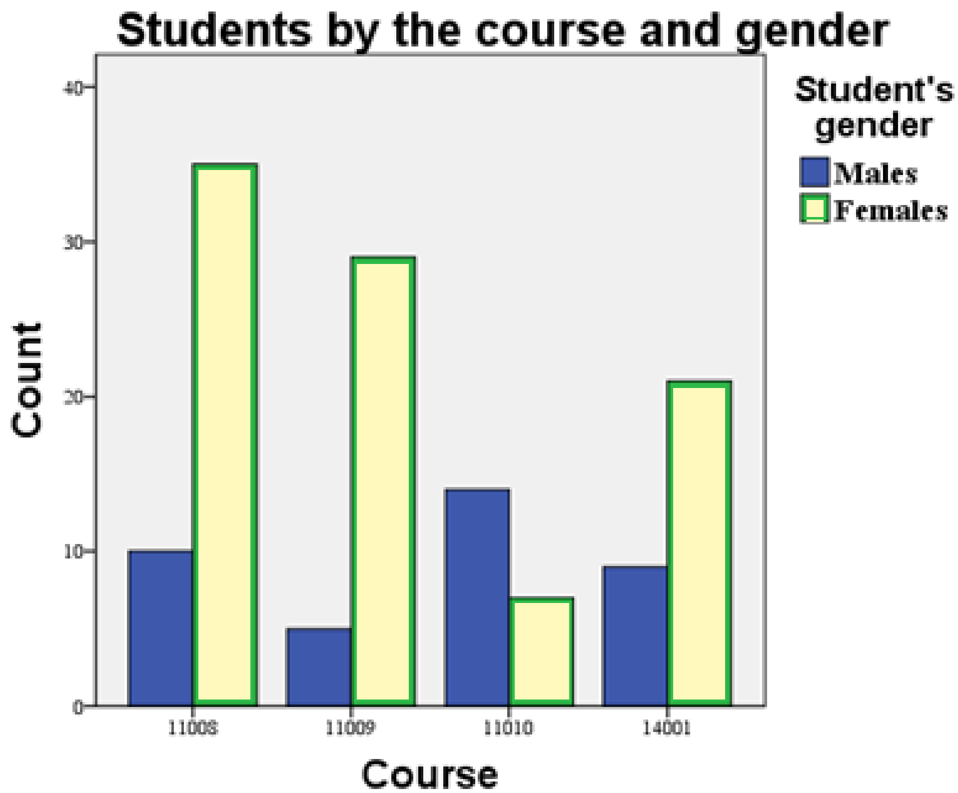


Figure 8. Student’s gender by the course.

Students’ age is presented in Figure 9. The majority of students, 65.4%, were 18 to 21 years old, 13.8% were 22 to 25 years old, 18.5% were older than 25 years, and 2.3% did not report their age.

Many students reported that they also had jobs: 13.5% worked 1-15 hours a week, 37.3% worked 16-25 hours a week, 23.8% worked 26-35 hours a week, and 9.5% worked more than 35 hours a week. Only 15.9% of students did not have a job. Figures 10-12 show how much students in each age group worked and how many courses they took at the same time.

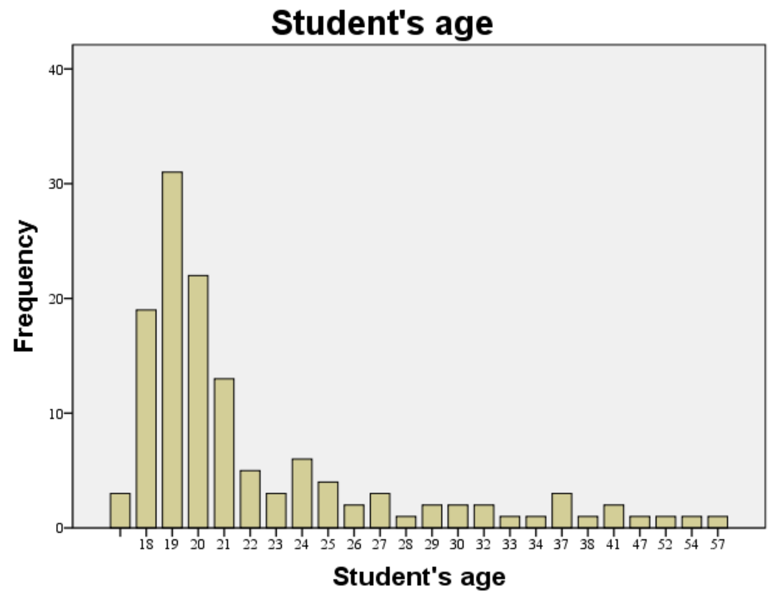


Figure 9. Student counts by age.

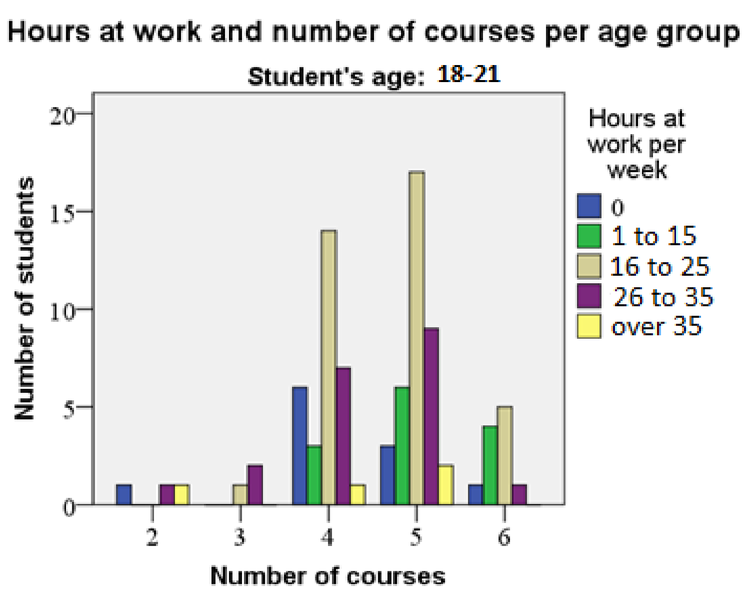


Figure 10. Hours at work and number of courses taken for the students of age 18 to 21.

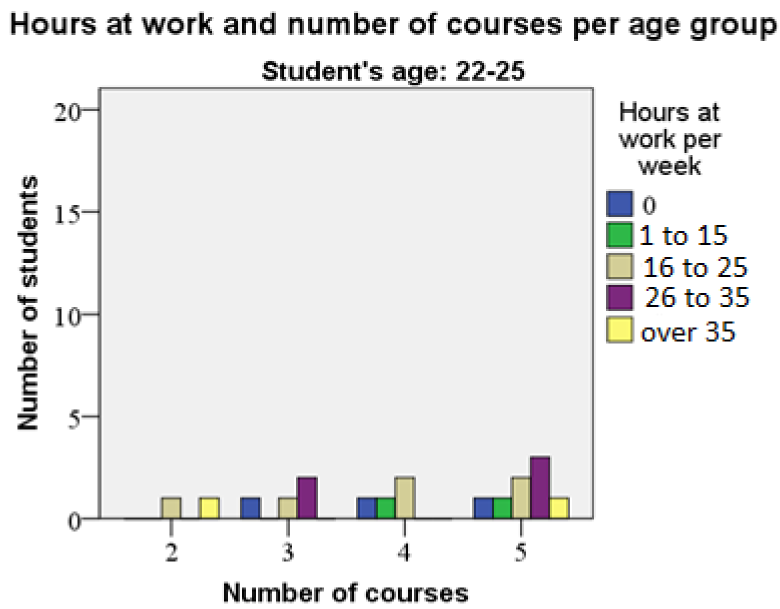


Figure 11. Hours at work and number of courses taken for the students of age 22 to 25.

Figure 12. Hours at work and number of courses taken for the students older than 25.

The majority of students were 18 to 21 years old (85 out of 130 or 65.4%) and almost all of these students (93%) took between four and six courses per semester. At the same time many of the students 18 to 21 years worked a significant number of hours each week: 36 (42%) worked between 16 and 25 hours a week while 24 (27%) worked over 26 hours a week. Overall, out of 85 students 17 to 21 years old, 56 (66%) worked more than 15 hours a week and took between four and six courses at the same time. These results indicated that many students had significant workload.

Students reported that they studied on average four hours a week. Figure 13 shows the percent of students who reported their study time as less than two hours per week, two to three hours per week, three to six hours per week, six to ten hours per week, and over ten hours per week.

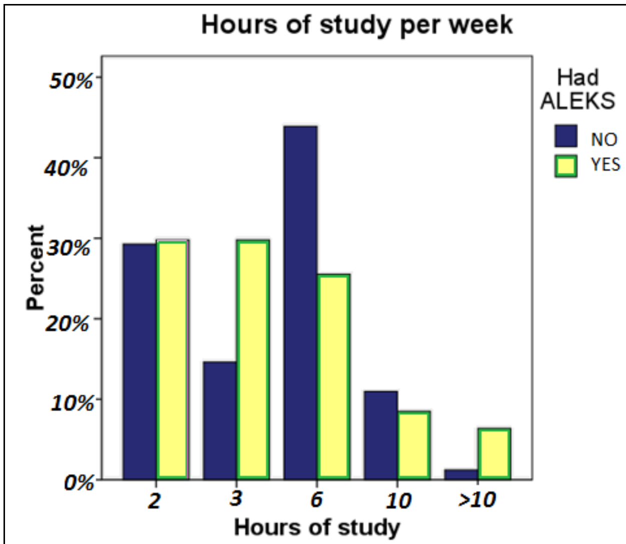


Figure 13. Percent of students by reported hours of studying per week.

An independent t-test was conducted and there was no difference on reported hours-of-study-per-week between ALEKS and non-ALEKS groups ($t(1,127) = 0.52, p = .959$).

Final Examination Scores - Research Question 1

The first research question asked: Is there a difference in final examination scores between former ALEKS students and students who did not take ALEKS emporium courses? This question was answered for each of the four courses. Students who withdrew from the lecture course or did not take a final were excluded. All tests were done with $\propto = .05$.

No statistical difference existed between former ALEKS students and students who never took ALEKS courses in any of the four courses. In three courses former ALEKS students scored, on average, lower than students who did not take ALEKS while in one course, former ALEKS students scored, on average, higher than students who did not take ALEKS courses. The results for each course are presented in subsequent paragraphs.

Explorations in Modern Mathematics

There were initially 45 participants within two sections but only 42 participants took their final and were included in the statistical processing. Sixteen participants were former ALEKS students and 26 participants did not take any ALEKS courses. The assumptions of the t-test were partially met (the normality of scores was violated):

- Independence is assumed because all finals were taken in a supervised environment.

- The normality of scores was violated. The Shapiro-Wilk test for ALEKS group had $p = .02$ and the non-ALEKS group had $p = .01$. Z-scores for skewness and kurtosis for both distributions were higher than 1.96 (the details are in Appendix F).
- Homogeneity of variance was not violated using Levene's test ($p = .378$).

Sixteen ALEKS students scored on average 80.625 ($SD = 18.504$) while 26 non-ALEKS students scored on average 82.846 ($SD = 16.785$). The result of the independent t-test indicated that the final score means for the ALEKS and non-ALEKS groups were not statistically different ($t = .401$, $df = 40$, $p = .691$).

Modeling Algebra

There were initially 34 participants within two sections but only 28 participants took their final and were included in the statistical processing. Nine participants were former ALEKS students and 19 participants did not take any ALEKS courses. The assumptions of the t-test were met:

- Independence is assumed because all finals were taken in a supervised environment.
- The normality of scores was not violated. The Shapiro-Wilk test for ALEKS group had $p = .263$ and the non-ALEKS group had $p = .127$. Z-scores for skewness and kurtosis for both distributions were less than 1.96 (the details are in Appendix F).
- Homogeneity of variance was not violated using Levene's test ($p = .210$).

Nine ALEKS students scored on average 73.944 ($SD = 20.464$) while 19 non-ALEKS students scored on average 78.421 ($SD = 12.930$). The result of the independent t-test indicated that the final score means for the ALEKS and non-ALEKS groups were not statistically different ($t = .707$, $df = 26$, $p = .486$).

Algebra for Calculus

There were initially 21 participants within two sections but only 15 participants took their final and were included in statistical processing. Seven participants were former ALEKS students and eight participants did not take any ALEKS courses. The assumptions of the t-test were met:

- Independence is assumed because all finals were taken in a supervised environment.
- The normality of scores was not violated. The Shapiro-Wilk test for ALEKS group had $p = .595$ and the non-ALEKS group had $p = .167$. Z-scores for skewness and kurtosis for both distributions were less than 1.96 (the details are in Appendix F).
- Homogeneity of variance was not violated using Levene's test ($p = .274$).

Seven ALEKS students scored on average 69.033 ($SD = 21.576$) while eight non-ALEKS students scored on average 53.786 ($SD = 15.408$). The result of the independent t-test indicated that the final score means for the ALEKS and non-ALEKS groups were not statistically different ($t = -1.591$, $df = 13$, $p = .136$).

Basic Mathematical Concepts I

There were initially 30 participants within two sections but only 29 participants took their final and were included in statistical processing. Ten participants were former ALEKS students and 19 participants did not take any ALEKS courses. The assumptions of the t-test were met except for kurtosis for non-ALEKS group where z-score was 2.020 (>1.96):

- Independence is assumed because all finals were taken in a supervised environment.
- The normality of scores was not violated. The Shapiro-Wilk test for ALEKS group had $p = .869$ and the non-ALEKS group had $p = .063$. Z-scores for skewness for both distributions were less than 1.96. Z-score for kurtosis for the ALEKS group was less than 1.96 but for the non-ALEKS group it was 2.020 (>1.96) indicating violation of kurtosis (the details are in Appendix F).
- Homogeneity of variance was not violated using Levene's ($p = .053$).

Ten ALEKS students scored on average 71.03 ($SD = 18.921$) while 19 non-ALEKS students scored on average 80.47 ($SD = 10.808$). The result of the independent t-test indicated that the final score means for the ALEKS and non-ALEKS groups were not statistically different ($t = 1.416$, $df = 12.177$, $p = .182$).

Self-reported-preparedness - Research Question 2

The second research question asked: Is there a difference in self-reported-preparedness between former ALEKS students and students who did not take ALEKS emporium courses? It provides insight into the following question: Are former ALEKS students more confident in their knowledge than students who did not take ALEKS emporium courses?

Statistical processing was done for all students regardless of their lecture course and also for each of the four courses separately. Students who withdrew from the course or did not take a final examination have not been excluded from this analysis. All tests were done with $\propto = .05$.

There were 130 students in all, 83 did not take ALEKS courses and 47 took some ALEKS courses. The bar graph presented in Figure 14 shows how students from these two groups rated their preparedness for the lecture course. The ALEKS group had a mean of 3.77 while the non-ALEKS group had a mean of 3.83, so both groups rated their preparedness, on average, close to very-good (4).

A Mann-Whitney U test indicated that self-reported preparedness did not differ between students who did not take courses in ALEKS ($n = 83, M = 66.90$) and former ALEKS students ($n = 47, M = 63.03$), $U = 1834.50, p = .556$.

The mathematics content covered in remedial courses delivered in ALEKS is not used to the same extent in subsequent lecture courses, so there was a chance that students would rate their preparedness differently in different lecture courses. The Mann-Whitney U test on the course level revealed that differences did not exist on the course level either – see the Table 4 below.

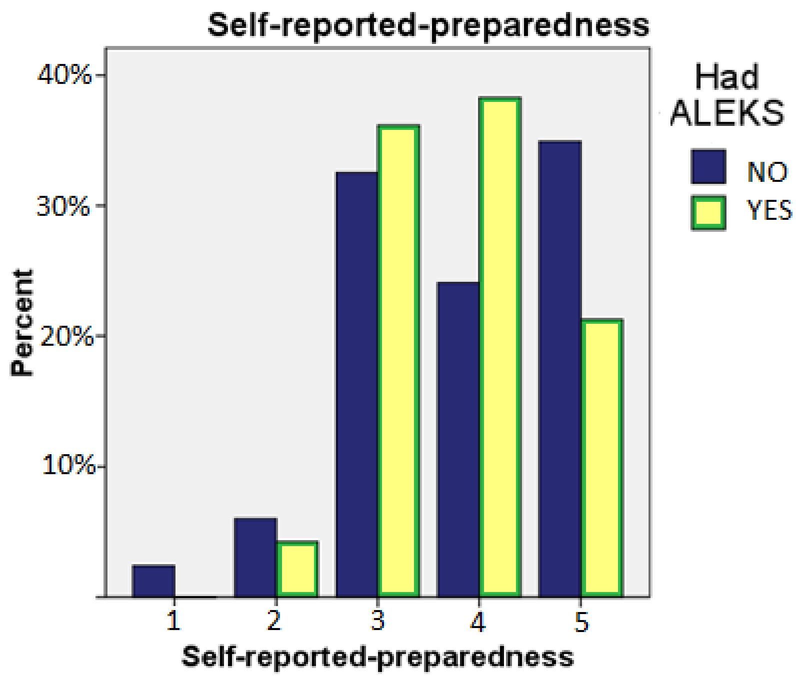


Figure 14. Self-reported-preparedness for students who did not take ALEKS courses and former ALEKS students.

Table 4

Mann-Whitney U Test for Self-reported-preparedness by the Course

Course	Non − ALEKS	ALEKS	U	p
Explorations in Modern Math	$n = 29, M = 23.97$	$n = 16, M = 21.25$	204.00	.483
Modeling Algebra	$n = 22, M = 16.89$	$n = 12, M = 18.63$	118.50	.608
Algebra for Calculus	$n = 13, M = 11.19$	$n = 8, M = 10.69$	49.50	.849
Basic Mathematical Concepts	$n = 19, M = 16.56$	$n = 11, M = 13.86$	86.50	.415

Self-reported-preparedness and Final Examination Score - Research Question 3

The third research question asked: What is the relationship between student self-reported-preparedness for the lecture mathematics course and the final examination score for former ALEKS students? What is this relationship for students who never took a course in ALEKS?

These questions were answered for each of the four courses and they provided insight into how students' confidence related to the results on the final examination, that is, how well students were able to judge their preparedness for the current lecture course. Students who withdrew from the course or did not take a final examination have been excluded from this analysis. All tests were done with $\propto = .05$.

The correlation between self-reported-preparedness and the score on the final examination was significant in only one sub-group (ALEKS group of nine students) of one course (Modeling Algebra). For the other seven sub-groups (three ALEKS groups and four non-ALEKS groups) no significant correlation existed, therefore students' self-reported-preparedness overall did not correlate to students' success in lecture mathematics courses. The results for each course are presented below.

Explorations in Modern Mathematics

A Spearman's Rank Order Correlation for sixteen students who took ALEKS courses indicated that there was no correlation between self-reported-preparedness and the score on the final examination ($n = 16, r_s = .041, p = .881$). A Spearman's Rank Order Correlation for 26 students who did not take ALEKS courses indicated that there was no statistically significant correlation between self-reported-preparedness and the score on the final examination ($n = 26, r_s = .177, p = .386$).

Modeling Algebra

A Spearman's Rank Order Correlation for nine students who took ALEKS courses indicated that there was a strong, positive correlation between self-reported-preparedness and the score on the final examination ($n = 9, r_s = .784, p = .012$). A Spearman's Rank Order Correlation for 19 students who did not take ALEKS courses indicated that there was no statistically significant correlation between self-reported-preparedness and the score on the final examination ($n = 19, r_s = .121, p = .620$).

Algebra for Calculus

A Spearman's Rank Order Correlation for seven students who took ALEKS courses indicated that there was no statistically significant correlation between self-reported-preparedness and the score on the final examination and ($n = 7, r_s = .409, p = .383$). A Spearman's Rank Order Correlation for eight students who did not take ALEKS courses indicated that there was no statistically significant correlation between self-reported-preparedness and the score on the final examination and ($n = 8, r_s = .125, p = .769$).

Basic Mathematical Concepts I

A Spearman's Rank Order Correlation for ten students who took ALEKS courses indicated that there was no statistically significant correlation between self-reported-preparedness and the score on the final examination and ($n = 10, r_s = .503, p = .139$).

A Spearman's Rank Order Correlation for 19 students who did not take ALEKS courses indicated that there was no statistically significant correlation between self-reported-preparedness and the score on the final examination and ($n = 19, r_s = .200, p = .411$).

Learning Experience in ALEKS - Research Question 4

The fourth research question asked: How do former ALEKS students rate their ALEKS learning experience? This question was answered for all students who took ALEKS courses regardless of the lecture course in which they were enrolled. Students who withdrew from the course or did not take a final examination have not been excluded from this analysis. The analysis was also done with respect to age, gender, and student academic status. All tests were done with $\propto = .05$.

The bar graph in Figure 15 represents how 47 students who took ALEKS courses rated their learning experiences in ALEKS on a scale of one to five, five being the highest. The mean value was 2.74 with a standard deviation of 1.170.

A Spearman's Rank Order indicated that there was no correlation between student's age and rating of ALEKS learning experience ($N = 45, r_s = .059, p = .702$). The data for two rows were missing.

A Mann-Whitney U test indicated that rating of ALEKS learning experience did not differ between males ($n = 15, M = 20.20$) and females ($n = 32, M = 25.78$), $U = 183.0, p = .179$.

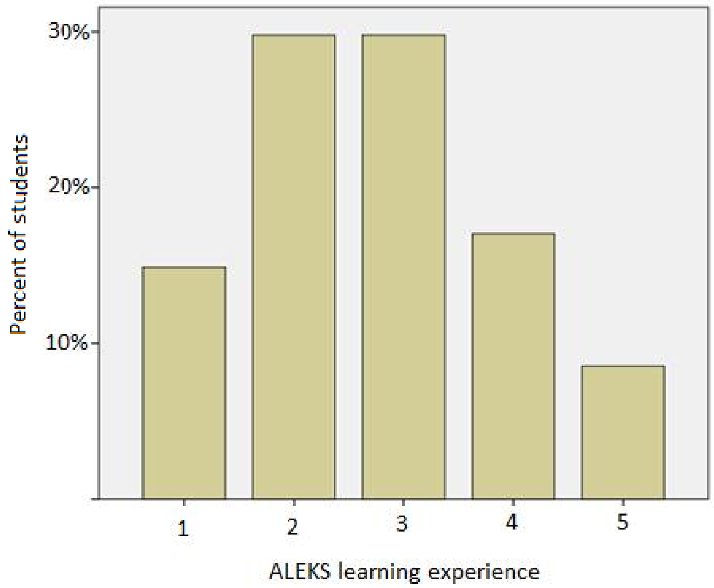


Figure 15. Percent of students who rated ALEKS experience on the scale one to five, five being the highest.

A Spearman's Rank Order indicated that there was no correlation between ALEKS learning experiences and students' academic standing ($N = 45, r_s = -.094, p = .537$). The data for two rows were missing.

Learning Experience and Number of Courses - Research Question 5

The fifth research question asked: What is the relationship between the number of ALEKS courses taken and student satisfaction with their ALEKS learning experience? Statistical processing was done for all ALEKS students regardless of the lecture course they were taking. Students who withdrew from the course or did not take a final examination have not been excluded from this analysis. All tests were done with $\propto = .05$.

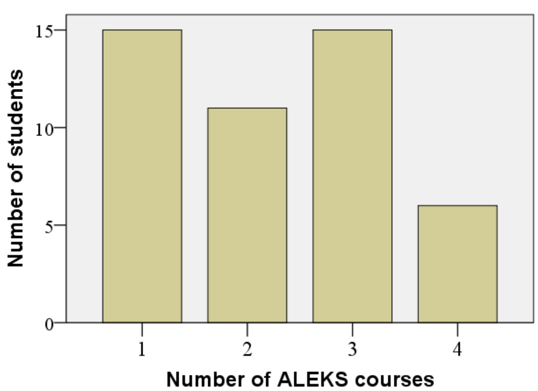
Table 5 below shows the number of ALEKS courses taken and students' rating of their ALEKS learning experience.

Table 5

The Number of ALEKS Courses Taken and Rating of Students' Learning Experience

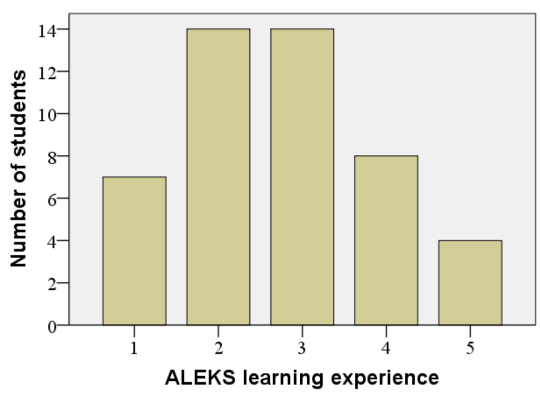
Number of ALEKS courses

		Number of students	Percent
Number of courses	1	15	31.9
	2	11	23.4
	3	15	31.9
	4	6	12.8
	Total	47	100.0



Students' Rate of their ALEKS learning experience

		Number of students	Percent
Rating	1	7	14.9
	2	14	29.8
	3	14	29.8
	4	8	17.0
	5	4	8.5
	Total	47	100.0



A Spearman's Rank Order Correlation for 47 students who took ALEKS courses indicated that there is no correlation between rate of ALEKS learning experience and the number of ALEKS courses taken ($N = 47, r_s = .223, p = .132$).

Open-ended Survey Questions about ALEKS - Research Questions 6 to 8

There were total of 47 ALEKS students in eight sections and cumulatively they completed 106 ALEKS courses in the previous school year. Students who withdrew from the lecture courses have not been excluded from this analysis.

The average rating of students' overall learning experience in ALEKS was 2.74 (the scale was one to five with five being the highest). The students also answered three open-ended survey questions about ALEKS:

- What was effective/good in ALEKS courses? (Survey question 10)
- What was ineffective/not-so-good in ALEKS courses? (Survey question 11)
- If you changed your learning and/or study habits because of ALEKS please describe how. (Survey question 12)

Codes in Tables 6-8 (Survey Question 10, Survey Question 11, and Survey Question 12) were derived from the students' answers. Only rows with a student response of 8% or higher are presented. Complete tables are presented in the Appendix D. Two coders coded the answers and any coding differences have been reconciled. As some students mentioned more than one item in some of their answers, the total number of coded responses was higher than 47 for each survey question.

For example, the first row of the table for "Survey Question 10" below can be interpreted in this way: 36% of former ALEKS students mentioned studying at one's pace as a positive feature of ALEKS emporium courses. They rated their overall ALEKS learning experience at 3.29 which is higher than the overall rate of 2.74. In other words, students who value learning at one's own pace appreciated ALEKS more than students on average did. Students who commented positively on learning at one's own pace took 35% of overall ALEKS courses.

The results for Survey Question 10 (What was effective/good in ALEKS courses?) are presented in Table 6. Thirty six percent of students liked being able to work at their own pace and they graded their overall ALEKS learning experience at 3.29 on average. Thirty two percent of students liked ALEKS content (good explanations and plenty of practice) and rated ALEKS learning experience at 3.33 on average. In both cases students rated ALEKS learning experience higher than the overall average of 2.74. It is interesting that 23% of the students responded to this survey question with a negative answer: "Nothing was good." These students rated ALEKS on average as 1.55. All other comments about effective features of ALEKS had less than 9% of a response rate and they were related to good feedback, organization, and good interface.

Table 6

Survey Question 10 with the Response Rate Greater than 8%

What was effective/good in ALEKS courses? Total number of coded comments was 54.				
CODE	Description	% out of 47 students	Students' rating of ALEKS	% out of 106 courses
01	ALEKS: Studying at one's own pace working on problem that I do not know until	36%	3.29	35%

	I understand			
02	ALEKS: Good content complete, covered all topics good explanations plenty of practice and review	32%	3.33	37%
99	Nothing was effective/good	23%	1.55	20%

The results for Survey Question 11 (What was ineffective/not-so-good in ALEKS courses?) are presented in the Table 7 and they indicate that 30% students reported that they missed lectures, a stronger student-teacher relationship, and a printed book; 23% did not like ALEKS content; 13% did not like ALEKS interface; 11% did not like some feedback features such as providing complete answers rather than hints for the next step when solving a problem and not explaining student's mistakes; and 9% found the course, overall, difficult. Some implementation features imposed by the school such as hours requirements, the course grade being determined only by the final score, and too many students per instructor were mentioned by 13% of former ALEKS students. The rest of the comments had less than 9% respondents and they included negative comments related to the use of computers, motivation to work, preparedness for the course, and courses overall, while four percent of students liked everything in ALEKS emporium courses.

Table 7

Survey Question 11 with the Response Rate Greater than 8%

What was ineffective/not-so-good in ALEKS courses? Total number of coded comments was 61.				
CODE	Description	% out of 47 students	Students' rating of ALEKS	% out of 106 courses
01	ALEKS: Missed lectures, printed book, and a stronger student-teacher relationship	30%	2.14	33%
02	ALEKS: Content - inadequate/incomplete - confusing - inadequate/confusing explanations - too many topics	23%	2.91	19%
03	ALEKS: Organization and interface - confusing, difficult - pie chart confusing - if you start low it takes a lot of time - progress tests can take mastery down significantly	13%	2.67	13%

04	ALEKS: Feedback issues related to content - not explaining student's mistakes - cannot ask computer if you still do not understand - feedback provides complete answers versus just hints thus NOT challenging students to think (too much reliance on help)	11%	2.60	9%
05	ALEKS: Feedback issues related to organization - unforgiving for typos - not able to revisit completed problems on tests - includes in progress tests topics not yet covered	9%	2.50	10%
06	SCHOOL: Organization issues - too many students per instructor so it is impossible to help all students enough, especially slower ones - grade determined by final score - hours required	13%	3.50	14%
09	Time consuming and hard to learn	9%	2.00	7%

The results for Survey Question 12 (If you changed your learning and/or study habits because of ALEKS please describe how.) are presented in Table 8. Eleven percent of students responded that they studied by themselves more and that they used tutors more while nine percent became more organized. A great majority of students did not change study habits (43%) or did not answer this question (28%).

Table 8

Survey Question 12 with the Response Rate Greater than 8%

If you changed your learning and/or study habits because of ALEKS please describe how. Total number of coded comments was 49.				
CODE	Description	% out of 47 students	Students' rating of ALEKS	% out of 106 courses
01	ALEKS: Students - study by themselves more - study using tutors more	11%	2.40	8%
02	ALEKS: Students started to study daily and became more organized	9%	2.50	9%
98	No answer	28%	2.31	30%
99	Nothing changed	43%	3.15	44%

Instructor Observations Related to Content - Research Question 9

The ninth research question asked: What strengths or weaknesses related to content did you observe when comparing current student groups to the ones in the past? Did former ALEKS students show some common strengths or weaknesses? This question was answered by each instructor for their course.

Explorations in Modern Mathematics

The instructor for the Explorations in Modern Mathematics reported that the current sections showed significant improvement in performance over sections in the past. One section was probably the best section that this instructor ever had and another section was above average. The instructor did not observe anything that would differentiate former ALEKS students and students who did not take any ALEKS course. The instructor taught Basic Algebra courses in ALEKS and considers it a very good drill-and-practice tool. The instructor felt lecture courses would, in general, benefit from an ALEKS-like tool because instructors would then have more time to devote to the students and to the development of critical thinking skills.

Modeling Algebra

The instructor observed that remedial mathematics courses in ALEKS appear to be doing a better job in preparing students for Modeling Algebra than the previously used lecture method in terms of students' persistence and confidence in their ability to deal with mathematics. The instructor mentioned that a longer observation period may be able to provide greater certainty that this initial observation was true. The instructor taught some ALEKS courses in the previous school year and thought that ALEKS provides great practice and is very good at determining what students are ready to learn.

Algebra for Calculus

To address differences in students' background, the instructor of the Algebra for Calculus course always provides a review of the mathematics topics that are required for the current course at the beginning of the course. The instructor did not observe differences between former ALEKS students and students who did not take ALEKS, nor were there differences noted between the current group of students and students from previous semesters. The instructor did not teach ALEKS courses but observed students using ALEKS.

Basic Mathematical Concepts I

The instructor for Basic Mathematics Concepts I course noted that topics that caused many students' errors were operations with integers and fractions. No differences were observed between former ALEKS students and students who did not take ALEKS. The instructor also felt the abilities of students over the past several years have declined and that was probably unrelated to the remedial courses being delivered in ALEKS emporium. The instructor taught ALEKS courses and observed that ALEKS was a great drill-and-practice tool.

Instructor Observations Related to Students' Behavior - Research Question 10

The tenth research question asked: Were there observable differences in students' behavior and expectations between ALEKS and non-ALEKS students? In other words, did the ALEKS environment affect students so that effects on the current course could be observed? This question was answered by each instructor for their course.

Explorations in Modern Mathematics

The instructor for Explorations in Modern Mathematics indicated that no observable differences existed between ALEKS and non-ALEKS groups. The instructor also mentioned that students were enthusiastic and willing to perform well.

Modeling Algebra

The Modeling Algebra instructor said that although students in this course generally do not like and are not interested in mathematics, the participants in this study demonstrated a positive attitude more often than in the past and were more open to the use of calculators and technology in general. The instructor characterized these observations as "some progress" related to the use of ALEKS and recommended that follow up studies be done over a longer period of time.

Algebra for Calculus

For the Algebra for Calculus course, the instructor indicated that new software was used in the course that included an e-book, practice problems, and assignments. The online material gave students a lot of practice. The instructor felt that students accepted the course software better than groups in the past, although was impossible to tell if current software was accepted better because the students were more ready to use it or because the software was better and that was the reason for improvement. The instructor identified two conflicting thoughts about the use of ALEKS. On one hand, the instructor thought that exposure to online software such as ALEKS early in a college program, may prepare students for the use of software in subsequent courses. On the other hand, the instructor thought that because ALEKS delivers customized instruction to each student, returning to lectures that are not individualized may be viewed as a disadvantage by students. Although Algebra for Calculus is structured, the deadlines for homework assignments were recommended but not enforced by the instructor. This flexibility gave students the opportunity to work at their own pace.

Basic Mathematical Concepts I

The instructor for Basic Mathematical Concepts I course indicated that this course does not use software that would allow self-paced study such as ALEKS, therefore students typically adjust to a lecture format. No changes in student behavior or expectations were observed by the instructor. The instructor felt that students typically want to pass the course so they seek help from the instructor and tutors when needed.

Instructor Observations Related to Course Adjustments - Research Question 11

The 11th research question asked: Were some adjustments necessary in lecture courses because of the former ALEKS students? If so, what and how effective were they? This question was answered by each instructor for their course.

Explorations in Modern Mathematics

The instructor for Explorations in Modern Mathematics indicated that no changes were done and none are planned for future sections in regard to the ALEKS students in two course sections involved in this study. The instructor stated that some changes in the course content may occur in the future as a result of regular course review.

Modeling Algebra

The instructor for Modeling Algebra did not make any course adjustments due to students who had taken ALEKS courses. The instructor did indicate that changes in the future courses are planned but they are not due to the needs of former ALEKS students.

The planned changes are mainly related to more use of technology and pre-recorded sessions.

Algebra for Calculus

Because the software was new, the instructor modified the Algebra for Calculus course in order to better integrate the new software. The instructor indicated that in the future, some additional features of the software may be incorporated into the course as long as those features are beneficial for the students and do not distract from the required content. The instructor also said that course content may be adjusted to better fit a 15-week semester. None of the planned changes are due to ALEKS.

Basic Mathematical Concepts I

For the Basic Mathematical Concepts I course, the instructor indicated that no changes occurred during the course due to ALEKS. In the future, the instructor plans to make some small content and organizational changes. The instructor also thought that using an ALEKS-like tool in this course along with the lecture would allow the instructor to focus more on the development of critical thinking and improved mathematics writing while the software would provide needed drill and practice of the mathematical concepts.

CHAPTER V

DISCUSSION

The objectives of this study were to evaluate the emporium course delivery in the intelligent tutor, ALEKS, by measuring student achievement in subsequent mathematics lecture courses, to analyze student and instructor perceptions of ALEKS, and to analyze ALEKS features from the perspective of intelligent tutors in general. This chapter contains the review of findings, implications, limitations, recommendations for future research and concluding remarks.

The Effect of ALEKS Emporium Courses on Final Scores in Lecture Courses

The main goal of remedial courses is to prepare students for subsequent courses so that they can perform at the same level as students who did not require remediation. Were remedial mathematics courses delivered in ALEKS emporium successful in achieving this goal? Did students who took ALEKS courses perform in subsequent lecture mathematics courses at the same level as students who did not take remediation?

According to the results of this study the scores on the finals in lecture courses between ALEKS and non-ALEKS groups were not statistically different. This was a positive result for the remedial courses in ALEKS emporium because students with weaker mathematical backgrounds who were required to take the remediation performed in the subsequent lecture courses at the same level as students who did not need this remediation. ALEKS emporium was a completely new and different course delivery from the traditional lecture courses that it replaced and from that perspective the result is very promising because further improvements in the course delivery are likely to produce even better results.

The analysis was limited to 114 students who took a final in four lecture mathematics courses that follow remedial courses. In all lecture courses ALEKS and non-ALEKS student groups were not different with the respect to gender, age, academic standing, hours of studying per week, number of courses taken, and hours of work per week. This indicates that all students belonged to the same student population regarding these variables.

Students' Self-reported-preparedness and the Rate of ALEKS Learning Experience

In addition to the comparable grades on the final examination between former ALEKS and non-ALEKS students, other indicators, such as students' self-reported-preparedness and their rate of learning experience in ALEKS, provided further insight into the effectiveness of ALEKS emporium courses. Former ALEKS students and non-ALEKS students did not differ in their self-reported-preparedness for their subsequent lecture course which aligns well with the fact that they, as groups, did not differ in the grades on their final examinations either. However, self-reported-preparedness for both groups was not a good predictor of student success in the respective lecture course indicating that students were not good judges of their knowledge. Taking ALEKS courses did not improve students' judgment of their knowledge (rigorous drill-and practice in ALEKS did not transfer into student's better self-evaluation of mathematics abilities).

Forty-seven former ALEKS students rated their learning experience in ALEKS at 2.74 on a scale of one to five, with five being the highest. The score was more than one point lower than the self-reported-preparedness score of 3.77. It seems that students thought that they were well prepared for the lecture mathematics courses they were enrolled in, but they may not have enjoyed or valued the learning experience they had in ALEKS. The qualitative portion of this study provided possible reasons for this seeming discrepancy in results from the two survey questions. Survey results also indicated that taking a greater number of ALEKS courses did not affect students' satisfaction with the ALEKS learning experience: no statistical correlation was found between the number of courses taken and the rate of students' learning experience.

Students' Comments about ALEKS Emporium

The analysis of open-ended research question "What was effective/good in ALEKS courses?" revealed that about one-third of former ALEKS students liked learning at their own pace and liked practice problems and the explanations provided. They rated their learning experience at 3.29 on a scale of one to five (the overall average was 2.74). One fourth of the students responded to the same open-ended question with the response "nothing was good" in ALEKS courses and they rated their learning experience at approximately 1.55.

When students were asked in the subsequent open-ended question what was ineffective in ALEKS emporium courses, about one third said that they missed lectures, a printed book, or were unable to sufficiently establish a student-teacher relationship; one third had some objections to the course content or found it difficult overall, while some students had negative comments related to the ALEKS interface or feedback features.

ALEKS emporium was a novel course delivery method for remedial mathematics courses, but only 24% of students reported changes in their study habits in the form of studying daily, using tutors more, or being more organized and independent. This result is somewhat surprising and indicates that teaching students how to learn online may be necessary in order to help students be successful and have a positive attitude. Teaching online-learning skills in remedial courses might also have a positive effect in subsequent courses that use online components or are completely online.

Observations by Instructors

All four instructors in the study were familiar with ALEKS emporium and three even taught ALEKS emporium courses. They viewed ALEKS as a very good drill-and-practice tool and mentioned that an ALEKS-like tool would be helpful in any mathematics course. However, for the development of critical thinking skills, the instructors considered lectures to be more effective and efficient than ALEKS.

The instructors were not able to differentiate between ALEKS and non-ALEKS groups in their lecture courses but they were able to compare current sections to ones in the past. One instructor observed that students appeared somewhat better prepared, that they were ready to use calculators, and were in general more confident and persistent in their work than the students from previous years when ALEKS emporium courses did not exist. The instructor suggested that longer follow-up studies be done to confirm these trends. One instructor observed that the exposure to ALEKS emporium courses was certainly helpful to his lecture course that also had an online component. One instructor felt students performed better than average while another reported steady student decline in mathematics knowledge over the last several years, but this observation was unrelated to the introduction of ALEKS. No adjustments were made in any of the lecture courses due to ALEKS indicating that former ALEKS students were sufficiently prepared and did not require any extra effort on the part of the instructors in the lecture courses.

ALEKS Emporium Design: Weak and Strong Features

We shall now review the features of ALEKS emporium that were brought up by the students, by the instructors who participated in the study, and by the researcher who also taught ALEKS courses for several semesters. The ALEKS emporium design strongly encouraged learning-by-doing: each ALEKS course had a certain number of problem types that students were supposed to know how to solve and the final test was entirely based on these problem types. The problem types, also called topics, were grouped in categories according to their mathematical content. After an initial assessment each student had sets of topics that he or she knew or was ready to learn. These topics were visually represented within corresponding categories in the student's "pie." The "pie" was the visual that students used to select a category and then a topic to begin their work.

As students worked on problems from the "pie," when they asked ALEKS for an explanation of a particular problem, they received a step-by-step solution that included links to the relevant sections in an online book. This process can be viewed as a somewhat weak integration of the book into the course because the center of activity was a “pie” with practice problems and students could choose not to use the book.

The “pie” and online book were intended to promote efficient online learning because the link would direct the student to the exact spot in the book that the student presumably needed. Students were expected to actively seek for a deeper meaning and understanding in the book as they worked on problems. Presenting the deeper meaning is an important part of traditional mathematics lectures but in emporium courses students could choose to work only on problems without considering the larger mathematical context or consulting a book or instructor. Insufficient or absent effort to contextualize and generalize the mathematics they were learning could be one of the reasons why some students found learning in ALEKS emporium too difficult despite the relatively easy mathematics content. Instructors’ observations about ALEKS as a very good drill-and-practice tool but lacking the development of students’ critical thinking skills indicate that instructors also thought that students probably did not benefit enough from the current ALEKS emporium configuration.

The visual representation of each student’s “pie” encouraged students to believe that the order of topics and categories that they chose to work on did not matter, but although they may have been able to do some problems from the advanced categories, for some problems in the advanced categories they had to learn pre-requisites first which meant that they had to go back to some earlier category. Unfortunately, based on their "pie," students could not determine pre-requisite topics that would allow them to progress in the current category and, as a result, they had to arbitrarily pick a category and available topic within that category. Because students had to master 80% of all topics, some students intentionally switched between categories and topics in the search for the familiar and easier problems so that they can fulfill the course requirement. The switching between categories and topics resulted in unorganized student notes for some students. Unorganized notes may not be a big problem for students who only need to refresh their knowledge, but for students who need to learn some topics for the first time, switching between topics and categories is likely to make learning very difficult and inefficient.

ALEKS emporium promoted self-study but when the topics were too hard for self-study, the students were expected to ask instructors for help. This was a very important emporium feature that was supposed to provide to students individualized mini-lectures when they were needed. Because instructors had no influence on students' grades, the answers to student's questions were also the primary way to build student-teacher relationships. However, 30% of students mentioned that they wanted stronger student-teacher relationship indicating that answering the student questions was not sufficient to build a strong student-teacher relationship.

Because students were expected to mostly study and learn mathematics content on their own, and the course design did not integrate the online book more closely, it is not surprising that some students found the courses difficult. The weak student-teacher relationship also indicated that students did not benefit enough from the instructor's help, however, it is unclear how often students asked for help. As the students' average rate of learning experience in ALEKS was 2.74, some other features of ALEKS emporium counterbalanced these negative aspects.

According to students, strong ALEKS features included learning at one's own pace, good explanations of problems and plenty of practice. The ALEKS interface was appealing visually, and no technical issues were brought up by students in the survey.

The researcher observed many ALEKS features as she was teaching ALEKS courses. ALEKS accurately identified which problems student did not know but was ready to learn. Practice problems were always randomly generated and as a result provided good practice. The explanations for problem solutions were detailed, contained links to the book, and, in some cases, additional tips. Students always received instant feedback on their practice problems and on their progress assessments. The book had good content and many practice problems as well. Two instructors who taught ALEKS courses also observed that ALEKS content was good.

Questions about how ALEKS is designed remain regarding how well online resources were used and if these resources were integrated well. As indicated earlier, students could choose not to use the online book.

Students raised some conceptual issues related to feedback: ALEKS did not explain students' mistakes and it also did not evaluate work steps, offer hints or tips, or recognize typographical errors. Instead, only final student answers were evaluated and complete step-by-step solutions were offered as feedback. It can be argued that in ALEKS emporium the instructors were available to provide hints or to find errors in students' work, but students had to ask for help first and instructors had limited time for each student.

From the survey results, students identified several technical design aspects of ALEKS that they considered as shortcomings. They pointed out the inability to revisit and correct problems on assessments. Some students' comments also indicated that they made incorrect assumptions about how ALEKS worked. For example, some students assumed that if their progress assessment included a problem that they did not learn yet and they did not solve it correctly, they were penalized but that is not true. ALEKS speeds up student's progress if the student correctly solves such a problem but does not apply any penalties if the solution is incorrect.

The following organizational issues were raised by students who rated ALEKS on average at 3.50 (as opposed to the overall average of 2.74): these students felt there were too many students per instructor and too many required hours of work in ALEKS. In addition, these students did not like the fact that the final grade in the ALEKS course was entirely dependent on the score on the final examination. Observations related to the course organization could be useful to the university when considering creating future modifications to the ALEKS emporium.

ALEKS and the Framework of Intelligent Tutoring Systems

Skinner (1964) predicted that machines would provide individualized instruction to students freeing instructors to help students individually and that is exactly what happened in Basic Algebra courses in the ALEKS emporium. Students worked in ALEKS and instructors were available for help. However, sporadic individual communication with an instructor was not sufficient for many students and they still missed lectures and a stronger student-teacher relationship. On the other hand, mathematics instructors viewed the intelligent tutor as a drill-and-practice tool rather than an effective primary mode of instruction delivery. They considered lectures as a more efficient and effective way of presenting content and developing the critical thinking skills that are required in mathematics. Therefore both students and instructors expressed some reservations related to the emporium delivery of mathematics courses. We'll review these reservations and ALEKS features from within the framework of intelligent tutors.

Both Camstra (2008) and Vandewaetere et al. (2011) identified frameworks for intelligent tutors that were similar (Table 1 was presented in the Learner Characteristics section of this study). The Vandewaetere et al. (2011) framework and its four models (expert model, learner model, pedagogical model, and interface model) will be used in this section to discuss ALEKS features when used in an emporium format.

The expert model represents the content and answers to the following questions indicate the quality of the content: Is the content comprehensive? How well is it organized? Does the intelligent tutor offer optimized assessments requiring a minimal number of questions? All the instructors in this study who taught lecture courses were familiar or even taught ALEKS courses and they agreed that ALEKS content was good, well structured, and well presented. The number of students who indicated that ALEKS provided good explanations was greater than the number of students who found content confusing or inadequate. The overall positive view of ALEKS content is not surprising because the content was reviewed and improved upon by many experts and continually evaluated through multiple student assessments. Although both online book and practice problems received mainly positive comments, the question remains how well they were integrated. ALEKS assessments were generated based on ALEKS content and on current student knowledge. As a result, the assessments rated student knowledge pretty consistently with a limited number of problems.

The learner model focuses on how the system tracks learner characteristics and how this knowledge is used to promote learning. ALEKS kept detailed information about each student's past performance and then used that information to guide that student's learning by offering only problems from the topics that a student was ready to learn. The instructors viewed this ALEKS feature as strong and effective. The students did not comment negatively about the function that guided them through problems so it can be surmised that the learner model had accurate information about each student.

Based on results from this study it is impossible to determine if and to what degree the learner model, as manifested in ALEKS, takes into account other learner characteristics such as cognition, meta-cognition, affect, and behavior. Theories of how these learner characteristics may be measured exist but there are not many empirical studies related to their implementation.

The pedagogical model is a part of an intelligent tutor that attempts to emulate human instructors and engage students as humans would do. The module that determined problem prerequisites and offered to the students only problems that the student was ready to learn did not elicit any negative student comments, therefore one conclusion may be that this aspect of ALEKS worked properly. The immediate feedback that ALEKS provided when students worked on problems, another component of the pedagogical model, was always a complete step-by-step solution. ALEKS had a very limited capability of recognizing student mistakes: for example ALEKS could recognize a fraction that needed to be simplified. Other feedback options such as offering hints, the evaluation of work steps rather than the final solution, and analysis of student mistakes were not available. Teaching students based on their mistakes (bug-related tutoring) was found superior to simply providing a correct response in Narciss and Huth (2006). Bug-related tutoring and hints for each step in problem solving would make ALEKS act more like a human tutor.

As an intelligent tutor, ALEKS is mainly focused on well represented content but it also utilizes knowledge tracing where a student's past performance is used to guide student learning and that makes it also adaptive. ALEKS does not use students' cognitive processes to guide students' learning as cognitive tutors based on ACT-R theory may do, but it does implement mathematical models in an attempt to eliminate careless errors and lucky guesses. From that standpoint ALEKS can be viewed as somewhat adaptive as well. The adaptation has many different aspects as described in Vandewaetere et al. (2011) and ultimately, different adaptation approaches taken in different theories such as ACT-R (Cognitive Tutors) and KST (ALEKS) may be integrated in the future intelligent and adaptive software.

The interface model of intelligent tutor deals with technical implementation, organizational implementation, and overall availability of the software. ALEKS did not receive any negative comments about availability which indicates stable and consistent technical performance. Some students negatively commented about an inability to revisit problems on exams. Some students did not like some organizational aspects of emporium courses and these issues were addressed by the university. Any software, including ALEKS, must keep up with future technology developments. The support of new devices that students may use is important, as well as the ability to integrate into larger educational systems by complying with the emerging standards for a universal learner profile. ALEKS keeps detailed information about past performances of every student rather than only scores on examinations. This information could be shared with other educational software through a universal learner profile. Sitthisak, et al. (2007) suggested that assessments in ALEKS could be useful as a model for developing meta-data for assessment in a universal learner profile.

Table 9 below is a summary of ALEKS emporium features mentioned in students' and instructors' observations as well as theoretical considerations of intelligent tutors that were presented in this study. Table 9 is by no means an exhaustive list of features of ALEKS emporium, rather it is an organized look at features that were brought up in this study.

Table 9

Student and Instructor Observations and Theoretical Considerations

Expert/content model (observations by the student and instructors)	Present in ALEKS
Well organized and high quality content.	Yes
Optimized assessments that cover the material with the least amount of questions.	Partial
Guide students based on the current knowledge (runtime adaptation).	Yes

Learner model (theoretical considerations)	Present in ALEKS
Student background and prior performance (knowledge tracing).	Yes
Learner cognition (learning memory capacity and cognitive style).	Not known
Meta cognition (self-assessment, help seeking, and help avoidance).	Not known
Motivation (desire for control, confidence, and independence).	Partial
Disengagement (off-task time and gaming the system).	Not known

Affect (happiness, joy, freedom, boredom, fear, and frustration).	Not known
Pedagogical model (observations by the students and instructors)	Present in ALEKS
The learner is guided based on the learner model.	Yes
The course content is closely related to the assessments and practice problems.	Partial
The instructional goals are explicitly related to the content and practice problems.	Partial
The student is guided through the structured material in the sequential fashion.	No
Instant feedback with all the steps on practice problems.	Yes
Instant grading on examinations (no detailed feedback is provided).	Yes
Option to guide the students through the problem by offering tips and hints for each step.	No
Option to analyze student mistakes and provide feedback on them.	Partial
Recognize typos and careless mistakes.	Partial
Support for online communication and data sharing.	Yes
Overall student satisfaction with the pedagogical model.	Partial

Interface, organization, and technological model (student, instructor, and theoretical observations)	Present in ALEKS
Allow learning on one's own pace and always available.	Yes
Interface functions are satisfactory.	Partial
Support for all devices that have web-interface.	Not known
Support for universal learner profile standards.	Not known

Intelligent tutors continually add features in an attempt to improve learning outcomes. ALEKS has very strong content features because dependencies between different mathematics topics are well defined and optimized. Based on the content we can say that ALEKS has high internal intelligence according to Camstra's (2008) definition. The learner model is highly intelligent related to the learner's mathematics knowledge, so it has a high external intelligence according to Camstra's (2008) definition but, at the same time, the learner model related to the affective and personal characteristics of the learner is probably very limited and therefore may be considered unintelligent. The pedagogical model is intelligent in guiding the student from one topic to another, but related to feedback it can be described as moderate to low intelligence because most sophisticated feedback types such as recognition of typographical errors, recognition of student mistakes, providing hints and tips, or evaluation of free-format content are not supported. The interface model is mostly technical implementation of the other three models and may be rated according to the user preferences rather than according to the level of intelligence. Overall ALEKS is more focused on content and from that perspective falls into the category of intelligent tutors although it does have some elements of adaptive tutors such as the module that attempts to recognize and eliminate lucky guesses and typographical errors as well as knowledge tracing.

Implications

The results of this study indicate that ALEKS emporium fulfilled the main requirement of preparing students for subsequent mathematics lecture courses. Despite satisfactory learning outcomes, former ALEKS students rated their ALEKS learning experience relatively low and almost one fourth claimed that "nothing was good" in ALEKS emporium courses and that the courses were difficult. The instructors who participated in the study viewed ALEKS as a very good drill-and-practice tool but not very effective in developing critical thinking skills. The instructors' insight may partly explain why some students found ALEKS emporium courses too difficult and the content confusing – they most likely could not derive enough deeper meaning and that made learning mathematics very difficult for these students.

The analysis of the design of ALEKS emporium courses revealed that students could complete problems as they were presented and not use the online book that would have provided deeper meaning. Tighter integration of the online book into the practice problems and assessments may result in better learning results for all students but may be especially valuable to the students who needed to learn some topics for the first time.

Although the “pie” design with free category and topic selection could have a motivational effect on some students, this positive effect may have been outweighed by the negative effects of unorganized student notes and less efficient learning. Both students who had to learn some topics for the first time and students who only needed to refresh their knowledge of some topics may benefit from a course design that was more ordered and prescriptive.

Weak student-teacher relationship reported by some students indicates that students either did not take the initiative and ask instructor’s for help or did not have enough opportunities to do so. ALEKS emporium may benefit from introducing a variety of assignment types in addition to practice problems. Different assignment types may not only engage students in different ways but they also could provide the opportunity for the meaningful student-teacher or student-student interactions to take place.

According to student comments, emporium courses worked well for students who appreciated learning at their own pace and who did not have difficulties with the course content while students who preferred lectures or had a hard time with the content resented emporium courses. The evaluation of ALEKS emporium (or any other educational software) using the systematic instructional design framework described in Dick, Carey, and Carey (2005) may be a good approach for discovering different learner types, their preferences, and potential pedagogical problems or needed enhancements ahead of time. Even when the software does not have a specific capability, in most cases that capability can be added into the course by engaging instructors and other resources. It is important to make sure that this added functionality fits well with the overall design.

As ALEKS emporium replaced lectures, the students had to actively seek for the deeper meaning in the online material instead of being presented with the deeper meaning through lectures. Students were also expected to seek an instructor's help when needed. ALEKS emporium was a novel type of delivery but not many students reported a change in their study approaches so it seems that these students may benefit from being taught how to effectively use online resources. Teaching students how to actively seek for deeper meaning and use different online resources must be gradual and deliberate. ALEKS emporium, by its nature, does not lend itself to a gradual introduction of an online environment, but ALEKS software can be used as a tool in lectures. In a lecture environment it would be possible to teach students gradually how to be more self-reliant. In fact, such an approach in remedial courses would be beneficial not only for subsequent mathematics courses, but for all college courses. The remedial program could be designed to require an increased amount of self-study as students progressed, and also to teach students how to utilize all available resources such as online course material, instructors, tutors, and student study groups. Given the importance of improving remedial courses, the college may consider offering both lectures and emporium options so that both students who prefer lectures and students who prefer self-study can be accommodated.

Even though the majority of students reported that they did not change their study habits, the ALEKS emporium most likely made an impact on other aspects of their learning. The instructors mentioned benefits such as the exposure to an online environment, repeated practice that resulted in more self-confidence, and a positive attitude towards using technology. Although there are multiple ways to measure these students' attributes, they are often measured through the achievement of learning outcomes and overall student satisfaction.

Students brought up several issues related to feedback and assessments that could be considered for future ALEKS software enhancements or could be implemented by changing the course organization. For example, students wanted ALEKS to provide hints rather than offering a complete solution, to evaluate their intermediate work steps, and to be able to recognize typographical errors. These features may be achieved either by adding new functionality in ALEKS or by adding assignments where instructors would provide feedback. Students also wanted to be able to revisit problems on tests and worried that they were penalized when ALEKS included questions on tests that they did not study yet and that they answered wrong. These concerns, too, can be either addressed by changes in ALEKS software or by changing how ALEKS is implemented in a course. Organizational issues such as too few instructors and too many required hours in ALEKS were already known and some have been addressed by the university.

Even the most experienced instructors constantly change their pedagogy, re-evaluate it, and adapt to current students. Intelligent tutor implementations must be re-evaluated regularly and adjusted to different student populations. Fortunately, intelligent tutors allow great implementation flexibility although their flexibility must be used carefully because, as Anderson et al. (1995) pointed out, unresolved curriculum issues may negatively reflect upon an intelligent tutor. Any problems in the implementation of intelligent tutors are hugely magnified when the implementations are large. It is as if one instructor was teaching in the exact same way a great number of students. In such instances, every possible implementation deficiency will be very visible. Early discovery of potential problems caused by the curriculum are one more reason why the evaluation of a complete implementation of an intelligent tutor using instructional design principles is necessary.

Intelligent tutors offer some highly desirable features such as individualized instruction, continuous availability, instant feedback, and exposure to an online environment. Their use in the future will only grow. When deciding when and which intelligent tutor to implement, educational institutions must consider the tutor's content, as well as learner, pedagogical, and interface models. Depending on the size and impact of the implementation, the evaluations may range from theoretical consideration of the implementation using an instructional design framework to large experimental trials that involve random selection of course sections, multiple pedagogical approaches, and both quantitative and qualitative research methods. Comprehensive evaluations may require expertise and resources that may not necessarily be available at every educational department. Such evaluations may benefit from the collaboration among various departments or from outside expertise.

From the theoretical framework of intelligent tutoring systems ALEKS had strong expert (content) and learner models while pedagogical and interface models could be improved. The use of systematic instructional design principles in future ALEKS software development and ALEKS implementations may produce even better results.

Limitations

The study was limited to one intelligent tutor (ALEKS), one mode of delivery (emporium), and one subject (mathematics). It would be helpful to know if similar results would be found in different ALEKS implementations in mathematics and in ALEKS implementations for different subjects as well. Investigations related to the effectiveness of different intelligent tutors through analysis of student success in subsequent courses would extend the knowledge of how students perceive intelligent tutors and in what ways intelligent tutors need to change in order to engage students more and better.

ALEKS emporium design features described in the study have been selected as important based on the observations made by students, comments by the instructors that participated in this study, and researcher's knowledge of ALEKS. The study results show that many design features shape the effects of the ALEKS emporium on student learning so it is possible that, despite all the efforts, some important features were missed.

The study was limited to students who passed ALEKS emporium courses and this limitation was appropriate given the main goal of the study. The study was limited to one regional campus of the Midwestern University. Students at regional campuses often work a significant number of hours on one or more jobs, and in some cases have significant family obligations which have a potential to affect their maturity, educational goals, and motivation and, with it, their expectations and evaluation of ALEKS. For a better generalization, this study can be replicated at the main campus where traditional students are in the majority. Different universities may have student populations that are more (or less) prepared to learn online and students from these universities are very likely to provide different answers on open-ended questions about the intelligent tutors.

Small sample sizes in some research questions caused the results to be strongly affected by sampling and only large effects could have been detected. The desired sample sizes can be computed based on the effect sizes and desired power (typically 0.80).

Student surveys rely on the accuracy of students' self-reported information and their willingness to provide their answers to the questions. Although the cases of missing demographic data in this study were very few, the students could misunderstand the questions and provide inadequate answers. Twenty eight percent of students did not answer the question about changed learning and study habits. It is possible that they did not know how to answer that question. Also, a part of this study investigated correlational relationships that do not imply causation.

The part of the research that was qualitative was susceptible to interpretation. Although two reviewers analyzed the responses to open-ended student-survey questions, there was always a possibility for misinterpretation. The interviews with instructors were re-evaluated through a member check but there remained the possibility of misinterpretation as well.

Open-ended questions on the survey may in the future be supplemented with the most common themes found in this study in the form of direct questions. For example, statements “I missed lectures” or “a student-teacher relationship was strong” could be evaluated by students using a Likert scale.

The study was limited in resources. Only one researcher collected and processed the data. Also the number of courses where one instructor teaches two sections of the same course as required in this study was limited. As a result only four out of five courses that follow Basic Algebra courses were represented.

Recommendations for Future Research

Many ideas raised in the Implications section could be tested in future research. The research can focus on ALEKS implementation, ALEKS design, course organization, and student population.

ALEKS Implementation

In ALEKS emporium, students can choose not to use the online book and only work on practice problems. This approach does not provide the deeper meaning that students could have derived if they had used the book and is especially damaging to weaker students. To ensure that students use the online book, the instructors could create assignments that would require it. For example, students may be asked by instructors to create their own online notes, examples, vocabularies, concept maps, and possibly share these items with the class. ALEKS, like the majority of intelligent tutors today, does not have a capability to evaluate free-format answers so any task that may require the evaluation of free-format answers would have to be evaluated by instructors or other students. The instructors' feedback would likely make the student-teacher relationship more meaningful as well. One way to measure the effect of this change would be to compare on final grades groups that had assignments that required reading the book to control groups that had assignments that did not require reading the book. Another approach could be to create an assessment that would test students on deeper understanding that is expected to be gained from reading the book, administer it to both test and control groups, and compare test scores.

Students' use of online resources and their ability to actively seek deeper meaning could be researched by analyzing metrics typically available with online resources today, as well as through assessments specifically created for that purpose.

Longitudinal studies would be very helpful in determining the trends in how students operate in an online environment and in identifying if a particular implementation of an intelligent tutor is effective. The metrics present in an intelligent tutor could be combined with very specific survey questions such as: "To what degree did you use the online book?" and "How many times did you ask your instructor for help?"

The findings and methods used in these future studies could both improve individual courses and help the development of future intelligent tutors.

ALEKS provides exposure to the online environment and, through the extensive drill-and-practice, reinforces the idea that repeated practice results in better learning. Direct questions about the value of repeated practice and attitude towards mathematics in future student satisfaction surveys may uncover additional consequences of students taking ALEKS emporium courses.

Future studies may assess different intelligent tutors in ways similar to what was done in this study. By reviewing results from multiple studies, using multiple intelligent tutors, the most effective features of intelligent tutors may emerge and direct the next generation of intelligent tutors and educational software.

ALEKS Design

In ALEKS emporium, students can choose not to use the online book and only work on practice problems. To ensure that students use the online book and gain deeper understanding of the material, problems that are directly related to important book segments could be added to the “pie” in ALEKS. One way to test the effect of this change is to create an assessment that would test students on deeper understanding gained from reading the book, administer it to both test and control groups, and compare test scores.

The effect of the “pie”-design on student learning could be tested by offering different visual representation of the course content to students in ALEKS. For example, categories could be represented as chapters in the content of the book rather than the circular presentation of the "pie." Each chapter could have a bar-chart indicating the percentage of a student's mastery. The summary bar graph could show the overall course mastery. The expectation is that such representation would discourage students from switching between topics too much and result in better learning outcomes. ALEKS tracks the number and names of topics attempted and completed in each study session so it would be possible to compare experimental (bar-chart) and control (pie-chart) groups on the number of switches between problem categories and number of abandoned topics. The groups could be also compared on the final test scores to determine if the design change had the effect on learning.

The following changes might somewhat improve students' rating of the ALEKS learning experience:

1. Students who missed having access to a printed book would most likely improve their view of ALEKS emporium courses if the book was readily available and closely aligned with the problems that students worked on in the course (the students in ALEKS emporium courses could print out portions of the book and examples of the problems but this was left to each student to organize and carry out).
2. Students who needed a stronger student-teacher relationship may have a positive reaction to video recordings of the course material. The recordings can either be a part of ALEKS software or created by their instructors.

Future versions of ALEKS software may provide better explanations to students of how the grading is done so that they do not worry about non-issues. Feedback functions could be made more robust by adding hints and tips, the evaluation of intermediate steps, and by expanding the function that recognizes typographical errors. The effects of the design changes could be tested in a controlled lab environment.

Course Organization and Student Population

ALEKS course organization may limit the negative effect of the "pie" without actually eliminating the "pie." Students can be discouraged from switching between categories in the "pie" by enforcing them to pass the test for each category before they move to the next one.

To teach students to learn online in ALEKS would require the re-introduction of lectures in some sections of Basic Algebra while keeping the ALEKS emporium in the rest. Lecture courses could use ALEKS as a drill-and-practice tool and also teach students gradually to effectively use the online environment. Examinations for all courses could still be in ALEKS to ensure that all students achieve an equal level proficiency level. Having both lectures and ALEKS emporium would allow students to pick the method that they prefer and this might also result in improved rating of students' learning experience.

The number of proposed changes and different implementation options in each change illustrate the great number of factors that affect learning outcomes. In most cases there is no time to test each proposed change separately. This is where systematic instructional design becomes helpful in uncovering the potential benefits and problems ahead of time. The great number of factors that influence learning and student satisfaction also explains why it is so hard to produce a statistical difference in educational research but as long as all design features are documented courses could be compared on learning outcomes.

If the goal is to improve ALEKS emporium at the institution where the study was conducted, the best approach would be to measure the current learning and satisfaction outcomes and then to implement changes that realistically can be done. Two main approaches can be considered:

1. Re-introduce lectures in some sections and keep ALEKS emporium as a self-study in the rest of sections allowing the students to choose which method they prefer. The lectures need to be based on ALEKS and designed so that they also teach students how to learn online.
2. Keep only ALEKS emporium but increase the instructor role by making the instructor responsible for assigning part of the grade.
3. In both cases 1 and 2, ALEKS implementation can be improved by design changes that will discourage students to switch between problem categories and by introducing a variety of assignments and tasks that also can promote instructor's feedback.

The majority of students in this study were 18-21 years old, they were taking four to six courses in the semester, and many also worked more than 16 hours a week. These demographics raised a concern that students' study time may have been limited due to their taking many courses combined with many work hours. Understanding a student population is essential to good instructional design. A separate study that would take into account a wider range of students' social aspects may be helpful in better describing the student population at this college and the results could be taken as an input into instructional design of all courses.

Conclusion

According to the results in this study, the ALEKS emporium implementation was a mix of positives and negatives. Former ALEKS students performed in subsequent mathematics lecture courses at the same level as students who did not take ALEKS courses, which is a good result, but overall students did not rate the ALEKS learning experience highly despite the good content and many good features of ALEKS software. The main problem appears to be the fact that students had no choice in the course delivery: lectures were not available and all students had to take ALEKS emporium courses. ALEKS emporium courses caused a strong division between students who enjoyed the individualized instruction offered in ALEKS and students who found individualized online learning too difficult.

Colleges must prepare students for their future careers which, in most cases, will require the ability to learn online. Online resources will be more common in all college courses and all students will have to eventually get used to learning online. The question remains as to how to make a transition to the online environment less abrupt and easier for students.

Modern software in the form of intelligent tutors offers valuable features that can enhance learning but students must actively look for a deeper meaning and use all available resources. These skills can be acquired only gradually. One way to build them is through carefully planned lecture or hybrid courses. ALEKS emporium courses did not offer this gradual introduction and some students negatively reacted to the change from a traditional classroom environment. One solution to this problem would be to offer both ALEKS self-study courses and lecture courses that would deliberately and gradually teach students how to effectively learn online in ALEKS. Although multiple course formats may introduce more administrative work, the importance of finding ways to deliver remedial courses that would satisfy the majority of students may justify it.

Intelligent tutor implementations need to be carefully considered and evaluated. A systematic instructional design framework is a good tool to discover potential implementation problems, such as inappropriate pedagogy for some groups of students, misaligned course material, or design issues, ahead of implementation. Because some implementation problems cannot be foreseen, comprehensive evaluation during software trials is very important. Large and complex implementations may require collaboration of multiple university departments or even outside expertise.

Intelligent tutors typically deal with high complexity in all four models (content, learner, pedagogical and interface). Although it is important to maintain the flexibility that allows different implementations, intelligent tutors should develop their pedagogical models based on systematic instructional design frameworks and principles.

The participants in this study identified numerous good features and shortcomings of the ALEKS emporium courses. It is important to obtain early and regular feedback from both instructors and students so that their input can be considered for the implementation and further improvements of the course delivery.

APPENDICES

APPENDIX A

STUDENT SURVEY QUESTIONS

Appendix A

Student Survey Questions

SURVEY QUESTIONS					
1	Student name (please print): ____________________				
2	Gender (circle one): **Male** **Female**			Age: ________	
3	Academic standing (circle one): **Freshman** **Sophomore** **Junior** **Senior**				
4	How many ***courses*** are you taking this semester: _____ If you have a job (even on temporary basis), please enter approximate number of hours per week: _____				
5	Circle the name of your course: **Explorations in Modern Math** **Modeling Algebra** **Algebra for Calculus** **Basic Mathematical Concepts**				
6	Rate how well you feel you are mathematically prepared for this course. Circle the score (5 being the most prepared): **1** **2** **3** **4** **5**				
7	How many hours per week do you study for this course? ____________				
8	List the semester, year, school and name of remedial mathematics courses that you took				
	Semester / year	School and course name	Semester / year	School and course name	
		KSU, Basic Algebra I in ALEKS			
		KSU, Basic Algebra II in ALEKS			
		KSU, Basic Algebra III in ALEKS			
		KSU, Basic Algebra IV in ALEKS			
Please answer the questions below only if you took ALEKS courses (otherwise you are done)					
9	Rate your overall learning experience in ALEKS. Circle the score (5 being the best learning experience): **1** **2** **3** **4** **5**				
10	What was effective/good in ALEKS courses?				

11	What was ineffective/not-so-good in ALEKS courses?
12	If you changed your learning and/or study habits because of ALEKS please describe how.

APPENIX B

INSTRUCTOR INTERVIEW QUESTIONS

Appendix B

Instructor Interview Questions

Questions for guided interviews with instructors are listed below. Each instructor participated in two interviews: the first one was between third and fifth week of semester and the second one was after the final exams. In order to obtain a member check, the interviewer restated or summarized the information during the interview and then asked the instructor for confirmation. The interview summary was sent to the instructor after the interview via e-mail for the confirmation and possible clarifications. The questions for the first interviews were:

1. The instructor name and teaching experience. How long have you been teaching and what types of courses did you teach?
2. If you taught ALEKS courses, what were they and how many times did you teach them? What features of ALEKS emporium courses (content, organizational, or technical) you find helpful or not so good?
3. What is the title of lecture course that you currently teach and that is included in this study? How long have you been teaching this course?
4. When was the last time that you taught this lecture course?
5. If there are differences in the student achievement, behavior and or expectations when comparing current groups to the ones in the past, please describe them.

If some differences transpire later, please communicate them as soon as they occur so that they can be tracked and discussed at the end of semester.

6. What kind of changes in your instruction or class organization do you plan because of the observed changes in student achievement, behavior and/or expectations?

Questions for the second interviews were:

1. The instructor name.
2. If you did some adjustments or changes in the class to accommodate current student groups what were they? Why the changes were necessary and how they worked?
3. If you plan additional changes for the future teaching of this course please describe them.
4. If you taught ALEKS emporium courses, what features of these courses (content, organizational, or technical) you find helpful or not-so-good for the current course?
5. If you attribute some of the differences in student achievement and behavior to ALEKS emporium courses, please share any suggestions for ALEKS courses that you may have.
6. Discuss any observations or concerns that may have been communicated to the researcher during the semester.

7. A random selection of former ALEKS and non-ALEKS students from your sections has been made. We'll discuss how selected students performed in the class in terms of writing mathematics (completeness and accuracy), timely completion of assignments, regular attendance, participation in class and any other items that you find important for the success in the course.
8. Final observations and comparisons of current sections to the sections in the past, related to students achievement, attendance, and behavior in class.

APPENDIX C

MATHEMATICS COURSES AND PLACEMENT SCORES

Appendix C

Mathematics Courses and Placement Scores

Columns "Placement test scores in ALEKS" and "Course placement" in Table 10 were retrieved from http://www.kent.edu/math/mathematicsplacement/pa-scores.cfm and they represent current mathematics courses that students can place into. The column "Score based on placement" in Table 10 was computed as arithmetic mean of the two percents in "Placement test scores in ALEKS." "Course placement" codes from student profiles determined their "Score based on placement".

Table 10: *Score Based on Placement for Existing Courses - Fall 2012*

Placement test scores in ALEKS	***Course placement***	***Score based on placement***
0% - 9%	Math 10020 (Pre-Algebra)	5%
10% - 24%	Math 10006 (Basic Algebra I & II) Math 10021 (Basic Algebra I)	17%
25% - 34%	Math 10022 (Basic Algebra II)	30%
35% - 44%	Math 10007 (Basic Algebra III & IV) Math 10023 (Basic Algebra III)	40%
45% - 54%	Math 10024 (Basic Algebra IV) Math 10041 (Elementary Probability and Statistics) Math 11008 (Explorations in Modern Mathematics) Math 11009 (Modeling Algebra) Math 14001 (Basic Math Concepts I)	50%
55% - 66%	Math 11010 (Algebra for Calculus)	61%
67% - 77%	Math 11012 (Intuitive Calculus) Math 11022 (Trigonometry) Math 12001 (Algebra and Trigonometry) Math 12011 (Calculus with Pre-Calculus I)	72%

78% or higher	Math 12002 (Analytic Geometry and Calculus I) Math 12021 (Calculus for Life Sciences)	89%

Some courses have been discontinued before the Fall semester of 2012 but still existed as placement courses in some students' profiles. For these cases, "Score based on placement" was assigned based on the course equivalency with the courses listed in Table 11.

Table 11: *Scores Based on Placement for Discontinued Courses – Fall 2012*

Course placement	***Score based on placement***
Math 10004 (Developmental Mathematics)	5%
Math 10005 (Introduction to College Mathematics) Math 10031 (Fundamental Mathematics I) Math 10032 (Fundamental Mathematics II) Math 10033 (Fundamental Mathematics III)	17%
Math 10034 (Fundamental Mathematics IV)	30%
Math 10035 (Fundamental Mathematics V)	40%
Math 10036 (Fundamental Mathematics VI)	50%
Math 11011 (College Algebra)	61%

APPENDIX D

CODES AND VALUES FOR STUDENT'S COMMENTS

Appendix D

Codes and Values for Student's Comments

There were a total of 47 ALEKS students in eight sections and cumulatively they completed 106 ALEKS courses in the previous school year. Students graded their overall learning experience in ALEKS at 2.74 on the scale of 1 to 5 with 5 being the highest. They also answered three open-ended survey questions about ALEKS:

- What was effective/good in ALEKS courses? (Survey question 10)
- What was ineffective/not-so-good in ALEKS courses? (Survey question 11)
- If you changed your learning and/or study habits because of ALEKS please describe how. (Survey question12)

Codes in the three tables below (Survey question 10, Survey question 11, and Survey question 12) were derived from the students' answers. As some students mentioned more than one item in some of their answers, the total number of coded responses was higher than 47 for each survey question.

For example, the first row of the table for the "Survey question 10" can be interpreted in this way: 36% of former ALEKS students mentioned studying at one's pace as a positive feature of ALEKS emporium courses. They rated their overall ALEKS learning experience at 3.28 which is higher than overall rate of 2.74. In other words, students who value learning at one's pace appreciate ALEKS more than students overall do. Students who commented positively on learning at one's own pace took 35% of overall ALEKS courses.

Table 12: *Survey Question 10 – All Codes*

What was effective/good in ALEKS courses? Total number of coded comments was 54.				
CODE	Description	% out of 47 students	Students' rating of ALEKS	% out of 106 courses
01	ALEKS: Studying at one's own pace - working on problem that I do not know until I understand	36%	3.29	35%
02	ALEKS: Good content - complete, covered all topics - good explanations - plenty of practice and review	32%	3.33	37%
03	ALEKS: Good organization and interface - reports - "student's pie" of math topics - ability to work from home	6%	3.00	9%
04	ALEKS: Good feedback - test results - review progress through the pie	6%	2.00	5%
80	Everything was effective/good	2%	4.00	4%
90	The answer could not be categorized	4%	2.50	3%
98	No answer	4%	2.50	5%
99	Nothing was effective/good	23%	1.55	20%

Table 13: *Survey Question 11 – All Codes*

What was ineffective/not-so-good in ALEKS courses? Total number of coded comments was 61.				
CODE	Description	% out of 47 students	Students' rating of ALEKS	% out of 106 courses
01	ALEKS: Missed lectures, printed book, and a stronger student-teacher relationship	30%	2.14	33%
02	ALEKS: Content - inadequate/incomplete explanations - confusing - too many topics	23%	2.91	19%
03	ALEKS: Organization and interface - confusing, difficult - pie chart confusing - if you start low it takes a lot of time - progress tests can take mastery down significantly	13%	2.67	13%
04	ALEKS: Feedback related to content - not explaining student's mistakes - cannot ask computer if you still do not understand - feedback provides complete answers versus just hints thus not challenging students to think (too much reliance on help)	11%	2.60	9%

05	ALEKS: Feedback related to organization - unforgiving for typos - not able to revisit completed problems on tests - includes in progress tests topics not yet covered	9%	2.50	10%
06	SCHOOL: Organization issues - too many students per instructor so it is impossible to help all students enough, especially slower ones - grade determined by one final score - hours required	13%	3.50	14%
07	Didn't like to use computers	4%	2.50	4%
08	Not motivated to work	2%	4.00	4%
09	Time consuming and hard to learn	9%	2.00	7%
10	Not prepared for the subsequent math courses.	4%	3.00	4%
80	Everything was ineffective/not-so-good (Nothing was effective/good)	6%	1.33	5%
90	The answer could not be categorized	0%	0	0%
98	No answer	2%	3.00	1%
99	Everything was effective/good	4%	4.50	5%

Table 14: Survey Question 12 – All Codes

If you changed your learning and/or study habits because of ALEKS please describe how. Total number of coded comments was 49.				
CODE	Description	% out of 47 students	Students' rating of ALEKS	% out of 106 courses
01	ALEKS: Students - study by themselves more - study using tutors more	11%	2.40	8%
02	ALEKS: Students started to study daily and became more organized	9%	2.50	9%
03	ALEKS: Reduced the reliance on calculator - able to do more math by hand	2%	5.00	1%
04	ALEKS: Students feel more independent	4%	2.00	4%
09	SCHOOL: Student study more because of organization - hours requirement	4%	3.00	3%
90	The answer could not be categorized	4%	1.50	4%
98	No answer	28%	2.31	30%
99	Nothing changed	43%	3.15	44%

APPENDIX E

THE GROUP EQUIVALENCY FOR THE RESEARCH QUESTIONS 1, 2, AND 3

Appendix E

The Group Equivalency for the Research Questions 1, 2, and 3

Explorations in Modern Math – for the research question 2		
Students who completed student survey were included. There were 45 students: 16 took ALEKS and 19 never took ALEKS.		
Processing	Statistical test	Statistic
Gender by group	Chi square test of association *	$\chi^2(1, n = 45) = 0.501$, $p = .479$
Age by group	Mann-Whitney U test	$U = 175.000, p = .295$
Academic standing by group	Mann-Whitney U test	$U = 200.500, p = .798$
Hours of studying per week by group	Mann-Whitney U test	$U = 222.000, p = .961$
Number of courses by group	Mann-Whitney U test	$U = 219.500, p = .755$
Hours worked at job by group	Mann-Whitney U test	$U = 201.500, p = .979$
* Some cells had count less than 5 so Yates' correction for continuity has been reported.		

Explorations in Modern Math – for the research question 1 and 3		
Students who took student survey and also completed a final were included (that is students completed the survey but withdrew or did not take the final examination were excluded). There were 42 students: 16 took ALEKS and 26 never took ALEKS		
Processing	Statistical test	Statistic
Gender by group	Chi square test of	$\chi^2(1, n = 42) = 0.265, p = .606$

	association	
Age by group	Mann-Whitney U test	$U = 169.500, p = .486$
Academic standing by group	Mann-Whitney U test	$U = 159.000, p = .396$
Hours of studying per week by group	Mann-Whitney U test	$U = 189.000, p = .767$
Number of courses by group	Mann-Whitney U test	$U = 207.500, p = .989$
Hours worked at job by group	Mann-Whitney U test	$U = 176.500, p = .921$
* Some cells had count less than expected so Yates' correction for continuity has been reported		

Modeling Algebra – for the research question 2		
Students who completed student survey were included. There were 34 students: 12 took ALEKS and 22 never took ALEKS.		
Processing	Statistical test	Statistic
Gender by group	Chi square test of association *	$\chi^2(1, n = 34) = 0.000,$ $p = 1.000$
Age by group	Mann-Whitney U test	$U = 131.000, p = .971$
Academic standing by group	Mann-Whitney U test	$U = 102.500, p = .739$
Hours of studying per week by group	Mann-Whitney U test	$U = 98.000, p = .217$
Number of courses by group	Mann-Whitney U test	$U = 105.500, p = .309$
Hours worked at job by group	Mann-Whitney U test	$U = 122.000, p = .880$
* Some cells had count less than 5 so Yates' correction for continuity has been reported		

Modeling Algebra – for the research question 1 and 3		
Students who took student survey and also completed a final were included (that is students completed the survey but withdrew or did not take the final examination were excluded). There were 28 students: 9 took ALEKS and 19 never took ALEKS		
Processing	Statistical test	Statistic
Gender by group	Chi square test of association *	$\chi^2(1, n = 28) = 0.000, p = 1.000$
Age by group	Mann-Whitney U test	$U = 76.500, p = .650$
Academic standing by group	Mann-Whitney U test	$U = 71.500, p = .976$
Hours of studying per week by group	Mann-Whitney U test	$U = 66.000, p = .333$
Number of courses by group	Mann-Whitney U test	$U = 72.500, p = .486$
Hours worked at job by group	Mann-Whitney U test	$U = 67.500, p = .484$
* Some cells had count less than 5 so Yates' correction for continuity has been reported		

Algebra for Calculus – for the research question 2		
Students who completed student survey were included. There were 21 students: 8 took ALEKS and 13 never took ALEKS.		
Processing	Statistical test	Statistic
Gender by group	Chi square test of association *	$\chi^2(1, n = 21) = 0.025, p = .874$
Age by group	Mann-Whitney U test	$U = 39.000, p = .480$

Academic standing by group	Mann-Whitney U test	$U = 31.500, p = .110$
Hours of studying per week by group	Mann-Whitney U test	$U = 37.000, p = .274$
Number of courses by group	Mann-Whitney U test	$U = 46.000, p = .641$
Hours worked at job by group	Independent sample t-test	$t = 0.013, df = 19, p = .990$
* Some cells had count less than 5 so Yates' correction for continuity has been reported		

Algebra for Calculus – for the research question 1 and 3		
Students who took student survey and also completed a final were included (that is students completed the survey but withdrew or did not take the final examination were excluded). There were 15 students: 7 took ALEKS and 8 never took ALEKS		
Processing	Statistical test	Statistic
Gender by group	Chi square test of association *	$\chi^2(1, n = 15) = 0.100, p = .751$
Age by group	Independent sample t-test	$t = 0.656\ df = 13, p = .524$
Academic standing by group	Mann-Whitney U test	$U = 22.500, p = .494$
Hours of studying per week by group	Mann-Whitney U test	$U = 22.000, p = .484$
Number of courses by group	Mann-Whitney U test	$U = 27.000, p = .901$
Hours worked at job by group	Independent sample t-test	$t = -1.425, df = 13, p = .178$
* Some cells had count less than 5 so Yates' correction for continuity has been reported		

Basic Mathematical Concepts – for the research question 2		
Students who completed student survey were included. There were 30 students: 11 took ALEKS and 19 never took ALEKS.		
Processing	Statistical test	Statistic
Gender by group	Chi square test of association *	$\chi^2(1, n = 30) = 0.437\ p = .508$
Age by group	Mann-Whitney U-test	$U = 93.500, p = .944$
Academic standing by group	Mann-Whitney U test	$U = 94.000, p = .810$
Hours of studying per week by group	Mann-Whitney U test	$U = 71.500, p = .153$
Number of courses by group	Mann-Whitney U test	$U = 61.500, p = .049$
Hours worked at job by group	Independent sample t-test	$t = 0.162, df = 28, p = .872$
* Some cells had count less than 5 so Yates' correction for continuity has been reported		

Basic Mathematical Concepts – for the research question 1 and 3		
Students who took student survey and also completed a final were included (that is students completed the survey but withdrew or did not take the final examination were excluded). There were 29 students: 10 took ALEKS and 19 never took ALEKS.		
Processing	Statistical test	Statistic
Gender by group	Chi square test of association *	$\chi^2(1, n = 29) = 0.206, p = .610$
Age by group	Mann-Whitney U-test	$U = 83.000, p = .899$

Academic standing by group	Mann-Whitney U test	$U = 88.000, p = .918$
Hours of studying per week by group	Mann-Whitney U test	$U = 70.000, p = .248$
Number of courses by group	Mann-Whitney U test	$U = 50.500, p = .030$
Hours worked at job by group	Independent sample t-test	$t = 0.641, df = 27, p = .527$
* Some cells had count less than 5 so Yates' correction for continuity has been reported.		

All courses – for the research question 2		
Students who took student survey were included. There were 130 students: 47 took ALEKS and 83 never took ALEKS.		
Processing	Statistical test	Statistic
Gender by group	Chi square test of association	$\chi^2(1, N = 130) = 0.256,$ $p = .613$
Age by group	Mann-Whitney U-test	$U = 1783.000, p = .752$
Academic standing by group	Mann-Whitney U test	$U = 1718.500, p = .745$
Hours of studying per week by group	Mann-Whitney U test	$U = 1807.500, p = .556$
Number of courses by group	Mann-Whitney U test	$U = 1657.500, p = .133$
Hours worked at job by group	Independent sample t-test	$t = 0.113, df = 124, p = .911$

APPENDIX F

SKEWNESS AND KURTOSIS RESULTS FOR THE RESEARCH QUESTION 1

Apendix F

Skewness and Kurtosis Results for the Research Question 1

Explorations in Modern Math – Skewness and Kurtosis for the research question 1.

Skewness

Group	Statistic	Std.Err	Z-score: Abs(Statistic/Std.Err)	Result
ALEKS	-1.166	0.564	2.067	> 1.96
Non-ALEKS	-2.622	0.456	5.750	> 1.96

Kurtosis

Group	Statistic	Std.Err	Z-score: Abs(Statistic/Std.Err)	Result
ALEKS	0.488	1.091	0.447	< 1.96
Non-ALEKS	9.665	0.887	10.896	> 1.96

Modeling Algebra – Skewness and Kurtosis for the research question 1.

Skewness

Group	Statistic	Std.Err	Z-score: Abs(Statistic/Std.Err)	Result

ALEKS	-1.280	0.717	1.785	< 1.96
Non-ALEKS	-0.028	0.524	0.053	< 1.96

Kurtosis

Group	Statistic	Std.Err	Z-score: Abs(Statistic/Std.Err)	Result
ALEKS	-1.834	1.400	1.310	< 1.96
Non-ALEKS	-1.260	1.014	1.243	< 1.96

Algebra for Calculus – Skewness and Kurtosis for the research question 1.

Skewness

Group	Statistic	Std.Err	Z-score: Abs(Statistic/Std.Err)	Result
ALEKS	-0.02	0.794	0.025	< 1.96
Non-ALEKS	-1.025	0.752	1.363	< 1.96

Kurtosis

Group	Statistic	Std.Err	Z-score: Abs(Statistic/Std.Err)	Result

ALEKS	-0.950	1.587	0.599	< 1.96
Non-ALEKS	-0.116	1.481	0.078	< 1.96

Basic Mathematical Concepts – Skewness and Kurtosis for the research question 1.

Skewness

Group	Statistic	Std.Err	Z-score: Abs(Statistic/Std.Err)	Result
ALEKS	-0.400	0.687	0.582	< 1.96
Non-ALEKS	0.093	0.524	0.177	< 1.96

Kurtosis

Group	Statistic	Std.Err	Z-score: Abs(Statistic/Std.Err)	Result
ALEKS	0.365	1.334	0.274	< 1.96
Non-ALEKS	2.048	1.014	2.020	> 1.96

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