Computer-Aided College Algebra: Learning Components That Students Find Beneficial

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In today's digital age, computers, email, cell phones, the Internet, and video games surround us. Today's student is extremely comfortable with the use of this digital technology. Today's classroom, however, is disengaged from the digital age; it is devoid of the technology that normally surrounds today's students. Prensky (2001) points out that our current educational system needs to change to meet the needs of today's student, a digital native. He suggests that mathematicians and mathematics educators should stop debating the use of computers and calculators in the teaching of mathematics, as they are a part of the digital natives' world and, instead, focus on how we can use them to help students learn the things we believe are useful.

While colleges and universities have primarily focused on distance learning (Tabs, 2003) and the use of graphing technologies, they are now responding more than ever to the educational possibilities of technology and to the needs of a new generation of digital learners. The National Center for Academic Transformation (NCAT) is an independent, not-for-profit organization that provides leadership in using information technology to redesign learning environments. Their efforts focus on producing better learning outcomes for students by creating environments in which students are active learners (Twigg, 2003). Virginia Tech was one of the pioneers in redesign of mathematics courses; with NCAT support, Virginia Tech developed their Math Emporium, a 500-station computer lab where students work at their own pace with the help of tutors and instructors (Moore 2001; Hodges & Brill 2007). Other institutions followed, modifying the emporium model for their own institutions. Louisiana State University, for example, required college algebra students to meet in a small class for one hour per week in addition to spending three hours per week in a computer lab staffed with tutoring support (Louisiana State University Department of Mathematics, n.d.). In all of these redesigns scenarios, students complete many of their assignments in an online course system that provides immediate feedback and a variety of materials and tools for learning the course content.

Research over the past decade has examined the effects of technology use on student learning. Pierce and Stacey (2001) found that students using a computer algebra system (CAS) spent more time in discussions among their peers.

Additionally, these students used the CAS to extend and clarify their understanding of the mathematics. Currently, colleges and universities are beginning to utilize online course-management systems (e.g., ALEKS, MyMathLab, etc.) as the primary source of instruction in their developmental and college algebra courses. For example, Taylor (2008) found that students had significant gains in algebra achievement when participating in a web-based intermediate algebra course using ALEKS (Assessment and Learning in Knowledge Spaces). Klein (2005) found no significant difference in student achievement between a traditional college algebra course and a traditional college algebra course that had access to the use of MyMathLab (MML) nor did using MML impact student attitudes. Additional findings from Klein's master's thesis revealed that students found entering the solutions into the computer to be frustrating and time consuming and that students felt "Help Me Solve This" and "View an Example" were the most beneficial components. Additionally, Spence (2008) explored student reactions to using the video tutor component of MML and found that students in the traditional lecture class with access to the video tutor used the video tutor regularly. In comparison, only two out of the five students in the online class continued using the video tutor after trying it out.

Background of the Study

During 2007–2008, researchers began to informally investigate a redesign of the college algebra experience at their large Midwestern land-grant university. Like many similar-sized institutions, the college algebra program at this university enrolls approximately 2,000 students annually as one of the entry-level mathematics course options. Course instruction may be characterized as traditional; experienced nontenured staff teach large sections (approximately 100 students), with lectures delivered in three 50-minute class meetings per week. Some of the motivations for considering a redesign included such issues as (1) less-than-desirable student success rates; (2) high student drop rates; (3) variability among sections and semesters with respect to grades assigned and content expectations; and (4) controlling costs of course delivery.

The investigation and resultant discussion guided the subsequent redesign effort. Using technology offered possible solutions to the issues at hand. Most importantly, the use of computers offered hope for increasing student learning. Augmented by online resources and instant feedback, the course could become a more active experience for students, with most of their time spent doing mathematics rather than passively watching mathematics. Evidence from other universities suggested that such changes can increase success rates and decrease drop rates (Twigg, 2003). Anticipated secondary impacts of the redesign included reducing variability among sections and lowering delivery costs. Since most coursework could be delivered online, all sections could work on comparable assignments and have similar grading standards. Automating some tasks using a computer projected to reduce costs, as each instructor could teach more students per section.

Rationale for the Study

In order to approach the redesign of the college algebra delivery system in a studied fashion, researchers designed and conducted a mixed-method study during the fall 2008 semester to better understand the experience of students participating in MML computer-aided instruction. The purpose of this study was to describe: (1) the MML computer learning components these students found beneficial; (2) their perceptions related to participating in MML computer-aided instruction; and (3) the ability of college algebra students participating in MML computer-aided instruction to effectively communicate their mathematical thinking in writing. This article represents discussions and findings relevant to describing which MML computer learning components students found beneficial. The relevant research questions guiding this portion of the study were

1. How do college algebra students describe the best way to learn in this computer-aided environment?
2. Which MyMathLab resources did college algebra students find the most beneficial and the least beneficial?

Methodology

Participants

Near the end of the fall 2008 semester, members of the research team visited each focus group and described the study. Students who chose to participate were given class time to complete a survey. Of the 319 students still enrolled in redesigned sections at that point in the semester, 215 returned the completed survey resulting in a 67.4% return rate. According to their responses to background questions on the survey, the median age of the participants was 18, and this class was the first math course at this university for almost 90% of them. Approximately 81.5% of the participants identified themselves as Caucasian, 6.5% as Hispanic, 3.5% as African American, 3.5% as Native American, 2% as Asian, and 3% as having multiple ethnicities.

Redesign Model

With the support of NCAT's Colleagues Committed to Redesign program, the mathematics department redesigned 8 of its 27 sections of college algebra during fall 2008. Each of the 8 redesigned sections met one time per week for 50 minutes in focus groups limited to 25 students (as contrasted with the regular sections that met three times per week for 50 minutes with enrollments of 50 students each). During these sessions, instructors reminded students about deadlines and course expectations, answered questions about the previous week's work, and previewed the upcoming week's content. Connecting with students once per week was viewed as important for keeping them organized and for maintaining a sense of class. Weekly task lists were also developed that provided a roadmap of tasks that the students should complete during the week.

In addition to the required focus group sessions, students in the redesign sections were also required to spend three hours per week in a computer lab that was open 60 hours per week and staffed by instructors and undergraduate tutors. While in the lab, students used the MML help features, videos, and online textbook to learn the week's content and to complete their homework and quizzes. The primary goal of the redesign model was shifting students' time from passively attending lecture to actively working on mathematics.

Computer Environment

The department chose an online course from MML, produced by Pearson Education, in part because it includes a wide variety of resources to help students learn the course material. When students are working on homework problems, there are links to many of these resources on their screen. Table 1 describes some of these features.

Table 1. Description of MML Components

Resource Name	Description
Help Me Solve This	An interactive, written tutorial that steps students through a problem and requires them to answer intermediate questions. When students have completed the problem with the help of this tutorial, MML generates a new problem for students to complete on their own.
View an Example	A detailed, written solution to a similar problem.
Textbook	An online copy of the relevant textbook section.
Video	A video lecture about the relevant topic.
Animation	A narrated animation about the particular topic.

Data Collection and Analysis

Each participant completed a survey consisting of both open-ended questions and Likert-scaled questions. Open-ended questions included questions dealing with the best way to learn in a MML section of college algebra, thoughts about their focus group in their learning, and their view of the most and least beneficial components of MML. Participants then rated each learning resource in MML on how useful they found them (not useful at all to very useful). Additionally, participants were asked to rate their level of agreement from strongly disagree (1) to strongly agree (5) with four statements dealing with whether they thought they had enough learning resources, enough support from their mathematics instructor, support from the tutors and staff in the Mathematics Learning Resource Center (MLRC), and whether they preferred submitting homework online or on paper.

Participant's responses to the open-ended questions and explanations of their Likert ratings on the survey were analyzed independently by three researchers using a constant comparative method (Strauss & Corbin, 1998). Researchers analyzed the data independently followed by a discussion of their individual coding schemes and a determination of appropriate categories. The participants' responses were analyzed independently again; this time the researchers placed the responses into these categories. Once again, the researchers came together to compare placement of responses. Any discrepancies were discussed and placed in an agreed upon category. Descriptive statistics (means and standard deviations) were calculated for the Likert scale ratings.

Results and Discussion

The findings are presented in two parts: students' descriptions of the best way to learn college algebra in a computer-aided environment and students' perceptions of the most/least beneficial resources for learning college algebra in a computer-aided environment.

Best Way to Learn College Algebra in a Computer-aided Environment

The participants responded to the following survey question:

> *You have a friend who is going to take a MyMathLab section of College Algebra next semester. Describe to her the best way to learn College Algebra in one of these sections.*

Analysis of responses revealed three major themes and two minor themes. Major themes included: Resources, Soliciting Help from Others, and Practice, Practice, Practice (See Table 2).

Almost half (45.6%) of all participants indicated they felt the best way to learn college algebra was through the use of resources (computer and textbook). Responses fell primarily within three categories: View an Example, video, and textbook. View an Example clearly was the favorite; it received more than twice as many responses as either of the other two categories. Video received only a few more responses than the textbook. Informative student responses included

- "Watch 'View an Example' for everything."
- "I would say to look at the 'View an Example' option. These take you through a step-by-step analysis of a similar problem that you are working on."
- "I think it depends on the person. The way I do my homework, I just use the sidebar to learn as I go. You can read the book and use the online videos to help you if you need to."

Table 2. Student Perceptions of the Best Way to Learn College Algebra in a Computer-aided Environment.

Theme	*n* (%)
Major Themes	
Resources (computer and textbook)	98 (45.6)
Soliciting Help From Others	96 (44.7)
Practice, Practice, Practice	63 (29.3)
Minor Themes	
Be Able to Teach Yourself	12 (5.6)
Do Not Procrastinate/Time Management	11 (5.1)

Almost half (44.7%) of the participants indicated that they felt the best way to learn college algebra was through soliciting help from others. Responses indicated that help fell into three areas: tutors, spending time in the MLRC, or attending a focus group. Participants indicated the need to take advantage of getting help from the tutors in the MLRC, and a few indicated getting help through a private tutor. One student commented, “Get help from the tutors in the MLRC, they are very helpful and explain it well to you.” In addition to tutors, students indicated taking advantage of the MLRC and focus group to ask questions. For example, one student stated that one should “go to class and the math lab each week and be sure to ask questions.” While this student found help both in the focus group and the MLRC, another student pointed to the MLRC as being more helpful, saying, “Go to the MLRC and ask the tutors for help. I didn't learn much in class simply because we weren't in class for more than 45 minutes a week, so to get that person-to-person time you have to ask questions in the math lab.”

The third major theme is “practice, practice, practice.” Approximately 30% of students mentioned that students need to practice to learn college algebra. Some students simply stated that this friend should do the course assignments; for example, one student wrote, “Do the homework, quizzes, and practice test always. It does help you for the test.” Several students stressed the need for repeated practice. Examples included, “Retake quizzes and homework problems as much as possible,” “The best way to learn how to do algebra is by doing the problems repeatedly until it gets stuck in your memory," and "Go over the problems you don't get over and over again." Some students conveyed a similar message by discussing the time spent on the course: "Dedicate time, tons of time." Other students recommended that their friend focus on understanding the material rather than simply completing problem. They wrote statements such as "… understand the homework don't just do it" and "actually learn the info instead of just clicking till you get the right answer." Similarly, a few suggested that their friend not try to hurry through coursework. One wrote, "Don't just fly through the homework, but take your time to work through it," and another said, "Don't try to rush the process."

Two minor themes revealed in the analysis included being able to teach oneself and time management issues. Twelve (5.6%) of the participants suggested that to be able to learn in a computer-aided section of college algebra, one must "be able to teach yourself." One student specifically said you should "be able to teacher yourself," and they went on to say that "the best way to learn is by teaching yourself the skills that you learn in the math lab by doing all your homework." Another student felt that the learning was similar to "intense independent studies." In addition to being able to teach themselves, eleven (5.1%) of the students indicated a need for time management, such as going to the lab to do the homework early in the week. For example comments included that one should not "put off going to the math lab," that one should "start on the homework early," and that one should not "wait until the last second to do your homework/quizzes."

While it does not answer the question posed, sixteen participants (7.4%) indicated that one should not take a section of a computer-aided college algebra class. One student was passionate about not taking the class, suggesting that one should "get the hell out of it and take a normal class." Another student stated, "Honestly, I would tell her not to take the computer math class. It's not the route to go." One student indicated that a computer-aided college algebra class was not for them, stating, "I understand that some people can learn in this environment, but I can't, so I would strongly suggest that they not even take this class. But, if they were absolutely forced to take this, I recommend that they brush up on note-taking skills."

A common thread among most of the responses is the concept of autonomous learning. Underlying many responses was the idea that students were responsible for their own learning. Students who wrote about resources directed their friends to particular tools to help them learn. Examples included: "Read the book! View examples"; "Don't just rely on MML computer videos and examples. It definitely helps to read the chapters"; and "The best way to learn is to press View an

Example and work out the problems step by step." These students developed strategies to navigate the course material as they worked independently. Students' strategies varied, but they all had to find methods that helped them. Some responses in the Practice, Practice, Practice theme emphasized that students need to reflect on their own learning as they do assignments; one student wrote, "Just make sure you know what you're doing before you move on." Even in the Soliciting Help from Others responses, students described taking actions themselves. Several students suggested that their friend ask questions to learn the material. One student said, "Go to every Focus Group. You are able to ask questions about problems to your instructor." Another student pointed out that it is most effective to ask for help after trying to think about the problem yourself: "The best way to learn is by first, trying to solve the problem by yourself using the given resources. If you still can't figure it out then ask the math tutor." Common among all of these themes is the action taken by the student. Students were responsible for developing and implementing strategies to learn college algebra within this environment.

Most/Least Beneficial Resources for Learning College Algebra

Participants were asked to think about the various learning resources (focus group, textbook, online textbook, videos, animations, view an example, help me solve this, tutors in the MLRC, and so forth) available to them and to identify which resource they found the most beneficial and those resources they found least beneficial to their learning experience; they also were asked to provide an explanation for their choices. Table 3 provides an overview of the resources that were identified.

In analyzing the most/least beneficial resources, the researchers coded the students' comments according to the available resources. Where students cited more than one resource, all were recorded. For example, one student responded to identifying the most beneficial resources by saying, "View an Example and Help Me Solve This. They offered step-by-step instructions for specific types of problems." This statement was coded twice among the available resources, once as View an Example and once as Help Me Solve This. Similarly, for the least beneficial resources, one student stated "Focus Group. But I never used the book, videos, animations, or tutors. So, out of what I used, the Focus Group was by far the least." After lengthy discussion, the researchers agreed to code Focus Group, Traditional Textbook, Electronic Textbook, Videos, and Tutors as the least beneficial resources. After all student comments and codings were recorded, the researchers revisited them to identify those resources that were singled out as most or least beneficial.

Table 3. Student Perceptions of the Most/Least Beneficial Resources to Learning College Algebra in a Computer-aided Environment

Resource	Most Beneficial	Least Beneficial
	n (%)	*n* (%)
Focus Group	15 (7.0)	41 (19.1)
Textbook	13 (6.0)	142 (66.0)
Traditional Text	2 (0.9)	95 (44.2)
Electronic Text	11 (5.1)	47 (21.9)
Videos	18 (8.4)	51 (23.7)
Animations	2 (0.9)	36 (16.7)
View an Example	145 (67.4)	11 (5.1)
Help me Solve This	32 (14.9)	17 (7.9)
Tutors in MLRC	48 (22.3)	16 (7.4)
Other	8 (3.7)	8 (3.7)

Note: Percents do not add up to 100% for either most or least beneficial as participants would list more than one resource.

In addition to identifying the learning resources students found to be most beneficial and least beneficial, participants were asked to indicate on a Likert scale (1, not useful at all; 5, very useful) how useful they found each resource in MML and to explain their rating (see Table 4).

Table 4. Rankings for How Useful Participants Found Each Learning Resource

Resource	1 *n* (%)	2 *n* (%)	3 *n* (%)	4 *n* (%)	5 *n* (%)
Focus Group	32 (14.7)	51 (23.4)	61 (28.0)	38 (17.4)	36 (16.5)
Traditional Text	117 (53.7)	41 (18.8)	33 (15.1)	20 (9.2)	7 (3.2)
Electronic Text	78 (36.1)	49 (22,7)	50 (23.2)	27 (12.5)	12 (5.6)
Videos	86 (40.4)	47 (22.1)	39 (18.3)	30 (14.1)	11 (5.2)
Animations	107 (52.5)	45 (22.1)	30 (14.7)	17 (8.3)	5 (2.5)
View an Example	3 (1.3)	3 (1.3)	6 (2.8)	26 (12.0)	178 (82.4)
Help Me Solve This	18 (8.4)	18 (8.4)	35 (16.4)	57 (26.6)	86 (40.2)
Tutors in MLRC	19 (8.8)	16 (7.4)	38 (17.6)	53 (24.5)	90 (41.7)

Note: Percents do not add up to 100% for either most or least beneficial as participants would list more than one resource.

In Table 4, results indicated that View an Example was the resource overwhelmingly found to be most useful while videos, animations, and the textbook (traditional or electronic) were the least useful. Participants' rationale for finding View an Example as useful (rankings of 4 or 5) indicated it provided them with a "step-by-step procedure for solving the problem" they were working on, with many indicating this is "how they learned." When examining the reasons that participants ranked videos as not very useful (rankings of 1 or 2), participants indicated either that the videos were "too time consuming" or that they had "never watched them." Analysis of participants' reasons for stating that the traditional textbook was not useful (rankings of 1 or 2) suggested that participants either never or barely used the textbook. Some indicated they only used the textbook to look up formulas, and one indicated they "needed the teacher to learn."

Further, more than half of the participants rated Help Me Solve This and the Tutors in the MLRC with either a 4 or 5, indicating they found them beneficial when learning college algebra (see Table 4). The rationales that participants provided for their rankings associated with Help Me Solve This included the following: it was an alternative to View an Example; it provided them with a step-by-step procedure; and it helped them find out where they had made a mistake or went wrong in their solution. Some participants even indicated that it was similar to View an Example but "more work to use to learn the same amount." An examination of the reasons for the high rankings for Tutors in the MLRC included: they found the tutors helpful, accessible, and knowledgeable. Additionally, the participants reported that they liked the human interaction, viewing the tutors as "the teachers."

Most Beneficial Resources. From Table 3, it is evident that View an Example surfaced as the most beneficial resource (mentioned by 145 students); 13 students (6.0%) identified this singly as the most beneficial resource. Tutors in the MLRC was second (mentioned by 47 students); 22 students (10.2%) identified it singly. Help Me Solve This was mentioned by 32 students; 19 students (8.8%) identified it singly. Combining the two most mentioned computer-only resources, View an Example and Help Me Solve This, accounted for 177 responses (82.3%); but only 32 students (14.8%) identified these singly. Interestingly, combining the single effects of Help Me Solve This and the Tutors in the MLRC, yielded 41 students (21.0%). It appears that students valued a computer resource coupled with a face-to-face resource over strictly computer resources.

Participants who chose resources such as View an Example and Help Me Solve This indicated they chose these resources because they provided them with step-by-step procedures to solve each problem (see Table 4). Very few of the students indicated that these helped them focus on and understand what was happening in the problem. This has led the researchers to ask questions such as (1) Do the types of questions that are being presented to students via the computer lead to and/or reinforce the belief that learning mathematics is just memorizing a set of procedures and not developing mathematical proficiency as outlined by the National Research Council (2001)? and (2) Do we need to reexamine the choice of questions being presented via the computer?

Least Beneficial Resources. From Table 3, the three resources identified as least beneficial were textbooks (traditional and electronic), videos, and focus groups. The Traditional Textbook was cited by 95 students as the least beneficial; of these, 76 students (35.3%) identified it singly as the least beneficial. For the Electronic Textbook, 47 students cited it as least beneficial; of these, 30 students (14.0%) identified it singly as the least beneficial. Taken together, 77 students (49.3%) identified the Textbook as the least beneficial resource. The Videos were identified by 41 students as next least beneficial; of these, 20 students (9.3%) mentioned it singly. Of the 41 students who identified the Focus Group as least beneficial, 25 students (11.6%) singled it out.

The results of this study suggest that students preferred resources that directly helped them with individual homework problems, rather than resources that emphasized the major concepts in each section or chapter. Their preference was to use learning strategies that were problem-specific, rather than those that helped them to create connections across problems. For example, View an Example, the most popular resource, gives students a complete solution to a problem that is often virtually identical to their homework problem. Getting help from tutors in the MLRC was another beneficial resource to students. This help also tended to be problem specific; one student wrote, “The best way to learn is by first, trying to solve the problem by yourself using the given resources. If you still can’t figure it out, then ask the math tutor.” On the other hand, the videos and the textbook tend to include discussion of the big picture of each topic and the common threads among problems; these resources were much less popular.

Students’ emphasis on figuring out individual problems is not particularly surprising. The heart of the issue may be their desire to minimize the amount of time and effort they spend on learning mathematics. We can gain some insight into this phenomenon by comparing students’ responses to View an Example and Help Me Solve This. While these resources are similar, the latter requires students to answer intermediate questions and to redo a full problem when they complete the tutorial. The former, however, shows a completed solution to a similar problem. A few students explained why Help Me Solve This was not quite as desirable for them. One wrote, “good, interactive but more work than View an Example but learn same amount.” Some of their reasons for not using the Videos and Textbooks also discuss time or effort. A student described the videos as “Too long and not to the point,” and another wrote that the textbook “takes too long to work with.”

Students’ preferences for resources that relate most directly to individual homework problems and for resources that give them step-by-step methods are consistent with their ambivalence towards the textbook. Based on this information about how students approached college algebra, the role of textbook in this type of course is unclear. With all the other resources at their disposal, do they need a textbook? If the textbook is still valuable, should it be exclusively in an electronic format, or is a printed text still necessary? What is the textbook’s purpose? One possibility is that the textbook needs to be redesigned to fit this new course model. Kirk Trigsted (2010) has developed an online college algebra textbook with Pearson Education to address this issue. The book is designed to be read online, with pages that fit on a screen to eliminate the need for scrolling and with clickable links to definitions and review material. Further research is necessary to evaluate the effect of redesigning textbooks for an online environment.

Conclusion

Because this delivery model does not follow the traditional customs that most students have experienced in their previous mathematics classes, there are questions that arise relative to the role of the student and how the expectations of increased learning autonomy are accommodated by the student. Further investigations are needed to answer questions such as (1) How comfortable are students with the increased autonomy of learning associated with this model? (2) How do students change their learning behaviors in an autonomous learning environment? (3) Does an autonomous learning environment contribute to a more conceptual approach to learning?

Students clearly stated that valuable components in the delivery model were View an Example and Help Me Solve This, suggesting a strong connection between success in the course and mastery of procedures, i.e., procedural learning. Students quickly learn that working very similar problems for homework and quizzes will lead to success. This observation gives rise to questions such as: (1) Do models like this one have a place in encouraging students to develop conceptual learning skills? If so, where? (2) Does the student perceived importance of procedural learning have a detrimental impact on conceptual learning? (3) Can this model be modified to encourage more conceptual learning? If so, how? and (4) What effect does computerized homework, quizzes, and exams have on the development of a student's mathematical writing skills?

There are also philosophic departmental issues and questions in addition to economic ones. (1) How well does this model fit into the overall mission of the department? (2) Several students (n = 16) indicated that the computer-aided college algebra class was not for them, implying that they could not learn in this environment. Why? What specific aspects of this delivery model contribute to this feeling? (3) How well does this model contribute to students’ meeting the prerequisites and expectations of subsequent mathematics courses? Will students entering calculus be prepared for a course emphasizing conceptual learning?

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