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Promoting Success in Applied College Algebra by Using Worked-out Examples in Supplemental Sessions

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Introduction

In 1986, 1.8 million of the 2.8 million (or over 64%) students who entered college for the first time left the first institution that they attended without earning a degree (Tinto, 1987). Although colleges and universities continue to develop programs to help retain students, Siedman (2005) states that recent retention data reveals a lower retention rate than Tinto reported in 1986. Mathematics is one discipline that gives students difficultly and contributes greatly to attrition. One of the reasons for this attrition is that many students who enter college are not prepared for the responsibility of college life or the demands of college-level courses. Gunawardena states that ``students who enter college are often under prepared and lack the background and motivation to succeed in college-level mathematics" (2002, p. 108). Ainsworth (1994) argues that students who come to college without an adequate background in math will likely withdraw from the course or quit performing when a math class becomes difficult. Students who are under prepared - and even those who are adequately prepared - fail to be successful because the class becomes difficult in their eyes and they don't believe that they can succeed. Mathematics is one subject in college that causes many difficulties for students in college.

Highlighted in Tapping America's Potential: The Education for Innovation Initiative report and A Commitment to America's Future: Responding to the Crisis in Mathematics and Science Education we find that students in America perform very competitively against international competition in mathematics and science. However, they tend to fall near the bottom or dead last by the final year. A Commitment to America's Future: Responding to the Crisis in Mathematics and Science Education states that ``nationally 22% of all college freshman fail to meet the performance levels required for entry level mathematics courses and must begin their college experience in remedial courses" (p. 6). Of the students that don't place into remedial courses, many enroll in college algebra. The enrollment in college algebra has grown recently to the point that nationally there are an estimated 650,000 to 750,000 students per year (Haven, 2007) and this number has surpassed the enrollment in Calculus each year. Although almost three fourths of one million students enroll in college algebra, it is estimated conservatively that 45% of these students fail to receive a grade of A, B, or C. Therefore, if 700,000 students enroll in college algebra then 315,000 students would fail to receive a grade of A, B, or C. The nonsuccess of students in college algebra occurs for a variety of reasons, including high school preparation, placement, content, attitude, pace of the course, pedagogy, motivation, and out of school commitment. To address the nonsuccess of students in an applied college algebra course at West Virginia University, the Institute for Mathematics Learning (IML) implemented weekly sessions devoted to working with students into the course structure. This article will discuss the structure of these weekly sessions and the effect on student success in the course.

Background and History of the Supplemental Sessions

In A Commitment to America's Future: Responding to the Crisis in Mathematics and Science Education, we find that ``few Americans, if any, can recall a time when the United States was not the world leader in mathematics, science, technology, and innovation. For decades, America has known no rival. The expansion of research and development in university and corporate laboratories, coupled with support for outstanding achievers in schools, colleges, and universities, fueled manufacturing productivity, reinvented entire industries and occupations, and created highly paid jobs." In recent years, the American students have been falling behind other countries students in both mathematics and science. It has been documented in A Commitment to America's Future: Responding to the Crisis in Mathematics and Science Education and Tapping America's Potential: The Education for Innovation Initiative; that United States is ``losing its edge in innovation and is watching the erosion of its capacity to create new scientific and technological breakthroughs" (pg. 3, 2005). America can not rely on the past to remain scientifically and technologically competitive in the international sphere, but rather has to increase the number of students in the science, technology, engineering, and mathematics pipeline to retain its status as a world leader. America is at a fork in the road. Will the United States wake up and establish itself again as a world leader or will it continue the technology crisis by remaining asleep?

West Virginia University founded the IML in the summer of 2001 to respond to this crisis. At the IML's inception, the Dean of Eberly College of Arts and Science stated ``during the past few years, we have become increasingly aware that U.S. high school students are not competing successfully with other students worldwide in mathematics and other areas of science. We believe it is critical to the success of our students - as well as for the future of our state and nation - to take a leading role in seeking answers to why U.S. students are behind in their math skills and to develop innovative methods to improve math instruction and leaning at the university level." The IML has been working on improving student success in introductory-level courses for the past seven years, included the following restructured, before calculus service courses: Liberal Arts Mathematics, Applied College Algebra, College Algebra, Trigonometry, Pre-Calculus, and Applied Calculus.

From 2001 to 2005, data was collected on student success in these and subsequent courses. The results from the Fall 2004-Spring 2005 academic year showed that students who earned an A or B in the restructured before-calculus course successfully earned an A, B, or C eighty percent of the time in subsequent courses. As Mayes, Chase, and Walker (2007) point out, these results provided ``evidence that the courses met an important criterion of validity." It was during the Fall 2004 - Spring 2005 academic year that Supplemental Practice was implemented in Applied College Algebra.

WVU first implemented Supplemental Practice (SP), under the direction of Dr. Robert Mayes. SP grew out of the efforts of the IML's efforts to improve students' success rates in Applied College Algebra. During weekly, one hour SP sessions throughout the first semester of implementation, students were given instructor-designed paper worksheets that focused on course skills or applications. One research question that researchers at WVU were trying to answer at that time was, what are the ``differential effects of focusing on algorithm skills or applications?" (Mayes, Chase, and Walker, 2007) Answering this question was unsuccessful when ``the algorithm sessions could not be separated from the application sessions." In Spring 2005, SP was updated so that questions the questions the questions used in the sessions came from a programmed text with well-documented success. McHale, Chirstensen, and Roberts (1986) authored the text. Using a Personal Response System (PRS), instructors implemented components of this text. Sessions were separated into SP sessions that focused on algorithms and SP sessions that focused on applications. For a particular topic, students in the SP algorithm sessions were presented questions that could be solved through procedures compared in the SP applications sessions, where students saw the same procedures, however this time through the context of real-world problems. For both the SP algorithm and application sessions, students were assigned to attend if they did not score an eighty percent after two attempts on a Diagnostic Assessment or if they scored below seventy percent at anytime on an exam. Therefore the SP algorithm and application sessions included both students who were required to attend and students who chose to attend.

Changes to Supplemental Practice and the Structure of Supplemental Sessions

Dr. Robert Mayes continued the Supplemental Practice through the Fall 2005 - Spring 2006 academic year. During the Fall 2006 semester, Dr. David Miller began coordinating Applied College Algebra and the Supplemental Practice Sessions. The only change that was implemented during the Fall 2006 semester was that attendance was not mandatory for students who scored below eighty percent on the Diagnostic Assessment or students who scored below seventy percent at anytime on an exam. During the Fall 2007 semester, Dr. Miller instituted three types of supplemental practices that ranged from totally passive sessions to totally active sessions. The three sessions were: 1) a totally active session where students worked in groups on the previous week's algebra problems through a worksheet consisting of problems similar to the assigned homework, 2) a totally passive session in which students wrote down questions from the material covered the previous week and turned them in at the beginning of the sessions. The supplemental session leader answered all the questions that students either turned in or asked verbally in the session. After all questions were answered the leader worked problems from the worksheet that had not been asked. Finally, 3) a passive/active session called the hybrid method where the supplemental session leader worked examples and then had student work similar problems.

Supplemental Sessions Using Group Worksheets

The supplemental practice sessions using group worksheets were designed for students to actively participate in solving problems and get one-on-one assistant from undergraduate and graduate class assistants. The researcher developed worksheets that consisted of homework problems similar to those assigned over the previous week and students were given the worksheets to work on in groups during supplemental practice sessions every Wednesday. During the session, the worksheets were given to every student and students were asked to work in small groups of three to five students. Students were instructed that they should talk with each other on how to solve the problems and ask the class assistants for help when needed. The eight class assistants and the researcher roamed around the class and would work with students on problems by writing on junior legal pads and handing the work to the group after the students understood their difficulties or the problem was solved. Student participation was recorded by taking attendance near the end of the class.

Supplemental Sessions Using Student Questions

The supplemental practice sessions using student generated questions is a more passive session, where students participate by submitting questions related to the previous week's class material on paper before the session started or by verbally asking questions during the session. The researcher classifies this type of session as passive because students participated in a more passive role, similar to lecture, where they copied solutions to student questions as the supplemental session leader wrote them on paper projected to a big screen in front of the class via the document camera. During a usual session, five to ten students would bring their hand-written questions to the supplemental session leader and most of the fifty minutes would be spent answering the questions. Any time left after answering the hand-written questions would be spent answering other questions students expressed verbally or similar problems on the group worksheet that had not been addressed in the session already. The researcher purposely designed the session so that any extra time could be used to go over uncovered questions from the group worksheets. This limited the differences between the sessions to the method in which the information was presented. That is, the two types of session covered very similar material but in totally different student participatory ways.

Supplemental Session Using the Hybrid Method

The hybrid method was constructed to show students more examples, but also to actively engage students in solving problems themselves. The method is based off of Worked-Out Example research in cognitive science (Sweller and Cooper, 1985). In the supplemental sessions using the hybrid method, the supplemental leader explains a problem from the previous week's course material and then requires students work a similar example. Once students have worked for a short time on the problem, the researcher asks students to state their answers and quickly goes over the solution if students have questions. This process is repeated over and over until the end of class.

Memory, Cognitive Load Theory, and Worked-out Examples

There are three types of memory: sensory, long-term, and working. Our senses -- sight, sound, smell, taste, and touch -- serve as stimuli for our sensory memory. Long-term memory, which is similar to a hard drive on a computer, is where the immense body of knowledge and skills is located. Finally working memory is where we think, solve problems, and are expressive. In general, everything that we "know" is stored in long-term memory and, through a query of working memory, activation occurs when needed. Miller (1956) says that working memory has a limited capacity that can deal with no more than about seven chucks of information simultaneously. One thing that helps to expand the capacity of working memory slightly is combining the senses to present information. Either some or all of the information will be lost during processing if the capacity of working memory is exceeded, unless information is recorded in a permanent form as it is being processed.

The discipline of cognitive science deals with the mental processes of learning, memory, and problem-solving. The total load on working memory at any moment in time is referred as the cognitive load. Miller's (1956) theory that most people can retain seven "chunks" of information in their working memory was the beginning of cognitive load theory. Simon and Chase's (1973) research, where they studied expert and novice chess players, showed that when expert chess players were presented with a game configuration that could occur during a regular chess game for a few moments and the configuration was then removed, they could reconstruct the same game configuration much better than novice chess players. However, when a configuration did not come from an actual chess game, expert and novice chess players showed no difference in their ability to reconstruct the game configurations. Just like the chess experts, problem-solving experts have an immense knowledge of problem situations and have constructed many mathematical schema, or “a cognitive structure that specifies both the category to which a problem belongs and the most appropriate moves for problems of that category” (Sweller and Owen, 1989) to activate when needed.

John Sweller (1988) developed cognitive load theory while studying problem-solving and has defined it to state that ‘optimum learning occurs in humans when one minimizes the load on working memory which in turn facilitates changes in long term memory’. Cognitive load theory, which deals with the architecture of human cognition, has broad implications for instructional design (Sweller, 1999) and current research is focused on differentiating three types of cognitive load: intrinsic cognitive load, germane cognitive load, and extraneous cognitive load. For further information on cognitive load you can start by reading the following papers can be referenced (Ayres, 2006; Sweller, 1988; Sweller, 2006; and Sweller, van Merrienboer, Paas, 1998). We will focus our attention on “The Worked-Out Example” research, which falls under cognitive load theory.

Generally, mathematics classes, as well as other STEM courses, are taught by lecturing on the new topic, presenting or demonstrating the concepts through a few examples, and assigning homework practice problems so students will learn the material that has just been discussed. The good students practice the problems assigned within a short time of the lecture and begin to master the material, while other students procrastinate for long periods of time before they decide to work the assigned problems. When students procrastinate or simply cannot focus on the covered material until a later time, they have more difficulty remembering what was said during lecture and/or details of the instructor's examples. Most, if not all, instructors use examples in class to illustrate the content's key principles to their students. However, students have little or no time to absorb the examples before another example or more theory is covered when taking notes in class. Sweller and Owen (1989) state that "some views of mathematics and the way it should be taught owe more to tradition than to our current knowledge of cognitive processes" (pg. 322).The worked example theory would place emphasis on worked examples in class by coupling problems solved in class with active student participation by having students work similar problems. In fact, research studies (Cooper and Sweller, 1985; Ward and Sweller, 1990; Zhu and Simon, 1987; Carroll, 1994, Tarmizi and Sweller, 1988) present students with a worked example on paper and tell them to study the example. Once the students are done studying the worked example, the instructor asks the student to solve a similar problem without any help from the worked example. It has been suggested that worked examples reduce the cognitive load on a student and might optimize schema acquisition (Sweller and Owen, 1989; Sweller and Cooper, 1985).

Worked examples are focused on skill acquisition in a subject and Trafton & Reiser found that "the most efficient way to present material to acquire a skill is to present an example, then a similar problem to solve immediately following" (1993, p. 1022). Worked examples have been used in a many different disciplines. To mention just a few studies that have been done in STEM fields: mathematics (Cooper and Sweller, 1985) and (Zhu and Simon, 1987), engineering (Chi et al., 1989), physics (Ward and Sweller, 1990), computer science (Catrambone, Yuasa, 2006), and chemistry (Crippen, and Boyd, 2007). Furthermore, A. Renkl has done studies in education with worked examples. One such study is (Hilbert, Schworm, and Renkl, 2004).

The research questions that will be addressed in the research are the following:

1. Do supplemental practice days, no matter the type, help students be more successful in the class?
2. Do students that participate in the supplemental sessions perform better on quizzes and exams compared to students that do not participate?
3. What is the best method to use in SP sessions in which students are the most successful in the course?

Literature Review

Sweller and Cooper (1985) conducted one of the first studies on worked-out examples. Through five experiments they examined the use of worked-out examples as a substitute for problem solving. The first experiment found that the more experienced students had a better cognitive representation of algebraic equations than less experienced students as measured by their ability to (i) recall equations, and (ii) distinguish between perceptually similar equations on the basis of solution mode. Sweller and Cooper (1985) concluded that there was “evidence that expertise in solving algebra manipulations problems is, at least in part, schema based.” (p. 67) It should be noted that during this experiment students were only asked to read and to make sure they understood the worked-out examples. Experiments 2 through 5 integrated an alternating pattern between worked-out examples and conventional problems because it increases the motivation for students to read and to understand the worked-out example if they have to solve another conventional problem immediately after the worked-out example.

The second experiment established that the worked-out example group (experimental group) required significantly less time during the acquisition phase than the conventional problem group (control group) and that the control group had a greater number of test errors than the experimental group.

The third experiment differed from second experiment by adding a self-explanation step after the worked-out example group read and stated that they understood the examples. The results of the experiment showed that worked-out example group spent significantly less time during both the acquisition phase and the test phase. The reason for the reduction in time is two-fold: (1) the worked-out example group had significantly less mathematical errors than the conventional problem group during the test phase, and (2) the conventional problem group sometimes unnecessarily expanded expressions which cause less efficient solutions.

The fourth experiment differed from previous experiments by varying the problems in the test phase from problems similar to the worked-out examples to problems that were structured differently (transfer problems) from the worked-out examples and conventional problem. This experiment wanted to determine whether students could transfer their knowledge from the acquisition phase to these transfer problems. Again the conventional problem group took significantly more time during the acquisition and test phase when each group started with a similar problem and then worked a dissimilar problem. In contrast, the two groups showed no significant difference in the test phase when each group was presented with a dissimilar problem and then a similar problem. Sweller and Cooper concluded that while “worked examples are of assistance to students when faced with similar problems, the advantage does not extend to dissimilar problems” (p. 83).

The final experimental setup was identical to the setup of fourth experiment. However, this time the worked-out example group and the conventional group spent the same amount of time during the acquisition phase of the experiment. It was hypothesized that the worked-out example group would be able to work through many more problems than the conventional group and hence perform even better during the test phase than the conventional group. Although the worked-out example group worked through more problems in the acquisition phase, the results were nearly the same as in the forth experiment.

Zhu and Simon (1987) demonstrated the feasibility and effectiveness of teaching mathematical skills through chosen sequence of worked-out examples and problems in a Chinese-middle school's algebra and geometry curriculum – and without lectures or other direct instruction.

Chi et. al. (1989) showed that while students studied worked-out examples, "good" students generally monitored their own understanding and misunderstanding through self-explanations. Compare this to "poor" students who did not generate sufficient self-explanations or monitor their learning inaccurately. They found "poor" students relied heavily on examples.

Ward and Sweller (1990) established that students who used worked-out examples formatted to reduce the need for students to mentally integrate multiple sources of information achieved test performances superior to either those exposed to conventional problems or to those shown worked-out examples that required students to split their attention.

We see that little research on worked-out examples have been conducted in college mathematics courses and worked-out examples have not been used very much in a classroom setting, let alone, large lecture courses. This study looks at this gap in the literature by looking a lower-level undergraduate mathematics course that is taught in large lectures. This study is in it's preliminary stage on this topic.

Methodology

The participants in this study were students in an applied college algebra course in a research university near the East Coast. Applied college algebra is one of three different college algebra courses at the university that is intended for students who did not place into the highest level of college algebra, but who did not place into the lowest level of college algebra either. The majority of students in applied college algebra are of traditional college age and do not go on to take calculus.

Quantitative data was collected through the grade sheet in the course and attendance data. The researcher had access after the semester to exam, quiz, and homework grades for all students. In addition, the researcher had access to attendance data, end of the semester grades, survey data through the universities data system, and answers to survey questions. Qualitative data was collected through interviews, informal discussions, and open-ended survey questions.

Discussion and Results

We have only collected some initial data on students' performance in the course given the number of supplemental sessions attended. This hints on how students who attend the supplemental sessions perform in the course compared to students who do not attend (or who only attend a few days). Success in the course can be defined two different ways: (1) a grade of C or above or (2) a grade of D or above. The two definitions of success would depend on the students' major. Some majors require a minimum grade of a D and some require a minimum grade of a C. When we look at the success rates in the Spring 2007 course versus the number of days that students attend the supplemental days (see table 1), we find that no student was successful if they attended 3 or fewer days. In addition, students who only attended between three and six days were not very successful in the course. We notice that 85.19% of the students who attended a minimum of seven supplemental days earned at least a D in the course, however only 38.89% earned at least a C in the course. Thus a majority of the students that attended seven supplemental days earned a D in the course. Students who attended nine or more supplemental days were very successful in the course for the most part. Almost all of the students earned grades of D or better and many earned grades of C or better.

Table 1

Supplemental. Days Attended	Spring 2007 Success rate (D & up)	Spring 2007 Success Rate (C & up)
0	0.00	0.00
1	0.00	0.00
2	0.00	0.00
3	0.00	0.00
4	33.33	33.33
5	22.22	11.11
6	68.18	36.36
7	85.19	38.89
8	85.29	58.82
9	100.00	81.48
10	100.00	75.86
11	93.33	66.67
12	94.74	89.47
13	100.00	81.82
14	100.00	71.43

We see with respect to the quizzes (see table 2), students that attended seven or more days of supplemental sessions were fairly successful (earning greater than a seventy average) on the quizzes. We notice that students that attended nine or more supplemental days earned grades of at least 80% on the quizzes except in the case of eleven supplemental days attended.

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Table 2

# of SS days	Quiz Average	# of students
0	21.66666667	2
1	11.33	10
2	28.33	4
3	22.22222222	3
4	38.33333333	3
5	51.67	9
6	65.45	22
7	71.60	54
8	74.71	34
9	81.9137037	27
10	83.05	29
11	78.44	15
12	84.47	19
13	81.96969697	11
14	83.10	7

With respect to course average (see table 3), we see that students who attended eight or more supplemental days earned a course average greater than seventy percent. Students who attended nine or more supplemental days earned a course grade of almost seventy-five percent except for the case of eleven supplemental days attended.

Table 3

# of Supplemental days attended	Course Average	# of students
0	10.615	2
1	16.185	10
2	22.615	4
3	20.893	3
4	35.630	3

5	45.078	9
6	63.376	22
7	67.040	54
8	71.746	34
9	75.354	27
10	74.963	29
11	73.771	15
12	77.838	19
13	76.625	11
14	75.579	7

Preliminary Conclusions

Research Question 1

Supplemental days were established in Applied College Algebra to help students be successful in the course and to understand the course material better. A variety of methods have been used in supplemental sessions in past semesters and the worked-out example method has been implemented completely in recent semester. Although we have not analyzed recent data on supplemental sessions that have employed worked-out example method, data from the Spring 2007 shows that supplemental sessions have been a positive intervention for students. It is somewhat surprising that no one of the nineteen students who attended less than four supplemental days passed the class and only three (out of twelve) students that attended four or five supplemental days, successfully made a D or C in the course (see table 4). At the point where students attended between six and eight days, only forty-nine (out of 110) earned a C or better, but ninety (out of 110) earned a D or better. Therefore twenty students (out of 110) did not pass the class even though they attended between six and eight.

Table 4

Supplemental Days attended	Total number of students	Number of D's	Number of C's	Difference
0	2	0	0	0

1	10	0	0	0
2	4	0	0	0
3	3	0	0	0
4	3	1	1	0
5	9	2	1	1
6	22	15	8	7
7	54	46	21	25
8	34	29	20	9
9	27	27	22	5
10	29	29	22	7
11	15	14	10	4
12	19	18	17	1
13	11	11	9	2
14	7	7	5	2

supplemental days. Students that attended nine or more supplemental days were very successful earning a grade of D or better and pretty successful in earning a grade of C or better. This can be seen by noting that 106 out of the 108 (or 98.15%) students that attended nine or more supplemental days earned a grade of D or better and eight-five out of the 108 (or 80.19%) students earned a grade of C or better. If we look further into the numbers of students that were not successful in the course, we see that of the majority of the fifty students (out of 249) that were not successful in the course, forty-three students attended seven or fewer supplemental days. Of the remaining seven students who were not successful in the course, five students attended eight days and two other students who attended eleven and twelve supplemental days, respectively. All of this is placed into more context with the fact that students were required to attended at 8 supplemental days this semester. Because some students were more motivated to succeed and therefore attended more supplemental sessions, student motivation can also be called into question. However, with the policy that students need to attend eight or more supplemental days, 107 students that did not meet this policy and forty-three of these students (or 40.19 %) did not successfully pass the class. Compare this with only seven (or 4.93%) of the 142 students that attended eight or more supplemental days (ie.. they met the policy) and who did not successful pass the class. Therefore there is evidence that supplemental practice days do help students in the course when students attend the majority of the supplemental days.

Research Question 2

Before we discuss what the data says about this question, we need to define what it means for students to "participate" in supplemental practice days. Participation will be defined by the student attendance at supplemental practice days. We define participation in supplemental practice as a student who attended eight or more supplemental days. The data discussed above was the reason why we selected eight or more supplemental practice days attended as the cut-off. We see in Table 5 that students who attended eight or more supplemental days outperformed students who attended less than eight supplemental days by 17% or more on quizzes, on exams, and in the course.

Table 5

	Average on Quizzes	Average on Exams	Course %
Participation	80.46	66.26	74.82
No Participation	58.16	49.1	54.37

Research Question 3

It is a little harder to get a hold on which method is the best method to implement in supplemental practice days. Recall that the two methods implemented in supplemental practice sessions were the group worksheets method and a question and answer method. The group worksheets allowed students to practice problems that were similar to problems in the homework. Furthermore some of the problems on the worksheets were similar to examples given in class during the previous week. We did not report any of the data on the worked-out example method which would help us determine which one of the three methods is the best method to use in supplemental sessions. Therefore we will only analyze this with respect to the group worksheet method and the question and answer method. We see from the table below that we can not conclude that one method was better than the other method all the time.

Table 6

Course average		
sec 1 (# of students)	sec 2 (# of students	Total # or students
8.70 (1)	12.53 (1)	2
23.95 (5)	8.42 (5)	10
14.87 (2)	30.36 (2)	4
19.18 (2)	24.32 (1)	3
N/A	35.65 (3)	3
51.22 (5)	34.84 (3)	9
62.55 (13)	64.57 (9)	22
66.10 (28)	68.01 (26)	54
73.78 (19)	69.17 (15)	34
75.35 (15)	75.36 (12)	27
75.28 (19)	76.26 (10)	29
74.35 (8)	73.11 (7)	15
80.03 (13)	73.09 (6)	19
74.38 (6)	79.32 (5)	11
72.25 (5)	83.90 (2)	7

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