JOURNAL OF

MATHEMATICS EDUCATION

AT TEACHERS COLLEGE

A Century of Leadership in Mathematics and Its Teaching

Promoting Equitable Practices in Mathematics Education

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JOURNAL OF **MATHEMATICS EDUCATION** AT TEACHERS COLLEGE | SPRING 2020 | VOLUME 11, ISSUE 1

Metacognitive Skills of Students in a Mathematics Class with Supplemental Instruction and Online Homework

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ABSTRACT Improving students' performance in Calculus is a challenge for many colleges and universities. One way of improving students' performance as well as their metacognition and study skills is to provide opportunities for them to receive support outside of the lecture. A modified version of the Motivated Strategies for Learning Questionnaire (MSLQ) was used to reveal any significant differences in metacognition and study strategies between students in a class with supplemental instruction with peer tutors and a dynamic online homework software (WebAssign), and students in a traditional class without these additional supports. Surveys and interviews were utilized to provide anecdotal evidence on the influence of WebAssign and supplemental instruction sessions on study skills and metacognition and whether students preferred WebAssign to traditional homework. Overall, the study showed no significant difference between the two groups in seven out of eight sub-scales of metacognitive skills and study strategies. Students reported that the supplemental instruction sessions and the WebAssign software were beneficial to their success.

KEYWORDS *calculus, metacognition, online homework, retention, study skills, supplemental instruction*

Introduction

The need to improve the performance of U.S. students in science, technology, engineering, and mathematics (STEM) is widely recognized (McGivney-Burelle & Xue, 2013; Zerr, 2007). In response to a growing concern that the U.S. is facing a crisis in college attainment rates, many programs in the New York Metropolitan area are promoting college access, success, and completion. The Percy Ellis Sutton Search for Education, Elevation, and Knowledge (SEEK) Program is one such program offered by the City University of New York at their senior (four-year) colleges.

One benefit of SEEK programs is supplemental instruction hours attached to high-risk academic courses. High-risk courses are defined as traditionally difficult academic courses that have a 30% or higher rate of D or F final course grades and/or withdrawals (Blanc et al., 1983; Kenney, 1988; Martin & Arendale, 1992; Peacock, 2008). Calculus, which is a prerequisite for many STEM disciplines, is a high-risk course. McGiveney-Burelle & Xue (2013) observed that despite the numerous efforts in recent decades to modify the teaching and learning of first semester calculus, this course remains a "gatekeeper" for STEM majors.

Supplemental Instruction and Online Support

Martin and Arendale (1992) define Supplemental Instruction (SI) as an academic assistance program that may increase student academic performance, retention, and metacognitive skills in high-risk courses. Metacognition can be defined as skills that learners acquire which demonstrate an awareness of their own knowledge and their ability to understand, control, and manipulate their own cognitive processes (Pintrich et al., 1991). SI is a proactive model where the peer tutor, called the SI leader, would attend all classes, and then hold tutoring sessions outside of class time. Martin and Arendale (1992) felt that the tutor could more effectively assist the students in this manner. SI differs from a tutorial program in that it integrates study skills for the course with content.

Martin and Arendale (1994) also defined the features of an SI program that contribute to students' success as follows:

- SI is proactive rather than reactive; it begins from the first day of classes.
- SI is attached to specific courses.
- SI leaders attend all class sessions.
- SI is not a remedial program.
- SI sessions are designed to promote a high degree of student interaction and mutual support.
- SI provides a way for the course instructor to receive feedback from the students through the SI leader.

Such features separate an SI program from other academic assistance programs.

In order to improve students' performance as well as their metacognitive and study skills, and to provide opportunities for students to receive peer and instructor support outside of the traditional lecture, out-of-class time should be highly structured to best prepare students for in-class activities (McGivney-Burelle & Xue, 2013). WebAssign is a versatile, web-based homework service for educators who want to offer expanded learning opportunities to their students (Risley, 1999). WebAssign is bundled with the textbook it uses. WebAssign and SI sessions are examples of structured out-of-class support that gives students immediate feedback on their homework.

WebAssign has several tools for instructors to use for teaching and assessing their students. It offers exercises, problems, simulations, videos, and tutorials for instructors to choose from in creating an assignment. Instructors can also access a dynamic gradebook, which shows students' performance on questions and topics throughout the course. Additionally, they can reuse the assignments created for other sections of the same course. Instructors can reply to extension requests on assignments made by their students. If instructors choose to administer graded examinations online, the WebAssign "LockDown Browser" prevents students from doing anything on the computer other than the examination.

Students have access to many features on WebAssign as well. WebAssign instantly grades the question as soon as they submit it, which allows students to receive immediate feedback. In addition to this feedback, WebAssign provides the opportunity to redo the question or a similar one. Students have multiple attempts to answer each question without losing credit for those questions. WebAssign has videos of course concepts and solved problems that students can use as a resource for learning. Students can click on "Practice Another Version" to solve a similar question for no credit if they need additional practice. Another resource for students is "Master It" tutorial which shows the solution to a problem step-by-step. The "My Class" Insights feature allows students to see the questions and concepts they mastered and those that require additional practice. When students need help or guidance on an assignment or a specific question, they can contact their instructors by using the "Ask Your Teacher" feature. There are additional questions, quizzes, and tests available that students can do, but are not graded for extra practice. Study guides are also available for students to review current and past concepts.

Methodology

The current study investigated the effects of SI and online homework on the metacognitive and study skills of first semester calculus students. The study addressed two research questions: (1) How do the metacognitive and study skills of students in a calculus class with SI and online homework differ from those of students in a traditional class? and (2) What are students' experiences with SI and online homework?

Theoretical Framework

McGivney-Burelle and Xue (2013) observed that in a typical calculus lecture, emphasis is placed on the lower cognitive level as defined in Bloom's Taxonomy. The six major categories of Bloom's Taxonomy are: Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation (Bloom & Krathwohl, 1956). Typically, when the students are solving homework questions on their own, they are expected to engage in the higher-level skills of *analysis, synthesis,* and *evaluation* without the support of their peers and instructor. SI sessions and WebAssign provide students the opportunity to receive immediate feedback on their homework.

In search of a theory of learning to improve metacognitive and study skills, Casazza & Silverman (1996) developed a theory consisting of four assumptions:

(a) Learning is an active process rather than a passive one,
(b) Individuals have to thinkabout a problem and reduce ambiguity before they can reach a solution,
(c) Motivational drive is intrinsic, and
(d) Before a learner can solve a problem, he/she needs to be able to look at the pieces of information that define the problem in different ways (p. 292).

The SI program was designed to increase students' metacognitive and study skills by fostering their growth as independent learners (Peacock, 2008).

Design

This study was conducted at a large, urban four-year college in the borough of Queens. It utilized Campbell and Stanley's (1963) Nonequivalent Control Group model since a true randomized design could not be achieved. The participants are students in two calculus classes: one where the students were given traditional homework assignments (control group), and the other where students were offered SI and online homework with WebAssign (experimental group). In this mixed-methods study, all participating students responded to items on a modified version of the Motivated Strategies for Learning Questionnaire (MSLQ) which is displayed in Appendix A. Due to the nature of the study, only the items in the learning strategies section of the MSLQ were included in the questionnaire that was used. To help gauge students' attitudes towards, and experience working with SI and online homework, a survey was created and administered. In addition, fourteen students from the experimental group were interviewed to determine what elements of the programed did and/or did not work for them.

The validation of true group equivalence in the control and experimental groups was not possible due to the lack of information regarding students' prior academic records. All students in the study were between the ages of 18-25 years. The control and experimental groups were similar with regard to demographic variables such as age, gender, class level, reason for taking the course, and the number of courses they were currently taking.

Three classroom observations were conducted throughout the semester. Both instructors began their classes by discussing homework questions which students voluntarily wrote and/or solved on the whiteboard. Following the explanation of new mathematical concepts or rules, students had the opportunity to solve some practice questions by themselves. In the experimental group, the supplemental instruction leader walked around the room helping students. At the end of the problem-solving session, both instructors explained and gave the answers instead of facilitating discovery by the students or asking students to explain their solutions. Both instructors referred to their prepared notes during the lecture. Based on the observations, it is safe to conclude that both instructors' presentation of course material and pedagogical strategy were similar. The only pedagogical difference between the two groups was the means by which homework was assigned.

Findings

Metacognitive and Study Skills

The items on the MSLQ related to Self-Regulation learning strategies measured how often students think about what they are reading, doing, or studying as they solve mathematics problems. This involves connecting new concepts to relevant aspects of prior knowledge, self-testing and questioning oneself to ensure understanding of the material, and continuously checking and correcting one's behavior as they proceed on a task. An independent samples *t*-test was conducted (see results in Table 1) to determine whether the students in the control and experimental groups differed significantly with regard to their Self-Regulation learning strategies. No statistically significant difference was found, which suggests that students in the SI/online homework sections and students in the traditional sections did not differ significantly in their awareness, knowledge, and control of cognition (Pintrich et al., 1991).

Similar results were found for Rehearsal, Organization, Critical Thinking, Time and Study Environment, Effort Regulation and Help Seeking. Basic rehearsal strategies involve rereading class notes and course readings and memorizing lots of key words and concepts (Pintrich et al., 1991). They are used to help students to retain concepts and recall them when needed. Organization strategies refer to students' ability to select the main ideas from class readings and organize what they need to learn in the course (Pintrich et al., 1991). These strategies require students to be actively engaged with the course material. Critical thinking refers to the degree to which students apply previous knowledge to new situations to solve problems, reach decisions, or make critical evaluations with respect to standards of excellence (Pintrich et al., 1991). Essentially, they enable students to look for evidence and/or alternative solutions and question theorems and other mathematical statements before accepting them as true. Time and study strategies involve scheduling, planning, and managing one's study

Table 1

Means for Metacognitive and Resource Management Strategies

Strategy	*N*	Mean	Std. Dev.	*t*	*p*
Self-Regulation				0.056	0.955
Control Group	56	3.62	0.51		
Experimental Group	56	3.61	0.61		
Time and Study Environment				-1.819	0.072
Control Group	56	3.74	0.49		
Experimental Group	56	3.91	0.49		
Effort Regulation				0.000	1.000
Control Group	56	3.16	0.51		
Experimental Group	56	3.16	0.51		
Help Seeking				0.482	0.631
Control Group	56	3.57	0.75		
Experimental Group	56	3.50	0.71		
Rehearsal				-0.287	0.775
Control Group	56	3.97	0.84		
Experimental Group	56	4.01	0.81		
Elaboration				-2.032	0.045*
Control Group	56	3.67	0.90		
Experimental Group	56	3.99	0.77		
Organization				-0.113	0.910
Control Group	56	3.68	0.77		
Experimental Group	56	3.70	0.89		
Critical Thinking				0.575	0.566
Control Group	56	3.34	1.03		
Experimental Group	56	3.23	1.02		

Note: The items are scored on a 5-point Likert scale with 1 meaning *strongly disagree* and 5 meaning *strongly agree.*

*$p < .05$

time and the use of a place of study (Pintrich et al., 1991). They entail the effective use of study time in a setting where the student chose to do his work. Effort regulation refers to students' willingness to try hard on their schoolwork, even when the work is difficult (Pintrich et al., 1991). These strategies include students' ability to stay focus on their schoolwork in the presence of difficulties and/or distractions. Help seeking involves students learning to manage the support of others (Pintrich et al., 1991). This enables students to seek help from others such as peers, tutors, and instructors outside of the classroom.

Elaboration strategies help students store information into long-term memory by building internal connections between items to be learned (Pintrich et al., 1991). These strategies include paraphrasing or summarizing course concepts and connecting new information to prior knowledge. An independent samples *t*-test (displayed in Table 1) revealed there was a statistically significant difference between the elaboration learning strategies of students in the two groups. The Cohen's *d*, which is used to measure effect size, for the learning strategy of elaboration was 0.4. This indicates a small effect size. That is, elaboration strategies have a small effect on students in the experimental group.

Online Homework and SI

Approximately 80% (45 out of 56) of the students agree (either "strongly" or "somewhat") the online homework using WebAssign helped them to better understand the course material and improve their problem-solving skills. One student said "WebAssign is helpful. It helps me answer the question(s) and it helps me to understand the material better." Almost all the students appreciated the benefits of having tutorial videos to watch when they needed help in solving a problem or understanding a particular concept. Another student commented "My favorite features are the videos, because I can actually see someone doing it [hands-on]." Ten out of fifty-six students mentioned that the feature that allows students to submit multiple attempts for a problem is one of the best aspects of completing online homework using WebAssign. One student mentioned "I like best that WebAssign gives some, at least five, chances without being penalized to get the answer right." On the other hand, one student noted that one could earn a good grade without actually understanding the concepts or even how to solve the problem since they can continue using the multiple attempt feature until they are correct.

Additionally, 48 out of 56 students responded that WebAssign helped them to be better prepared for tests and 42 out of 56 responded that the software helped them score higher on tests. Other responses included students responding that their time spent on WebAssign was worthwhile (40 out of 56) and that homework using WebAssign was more beneficial to their success than traditional homework completion (35 out of 56). Ten of the fourteen students interviewed agreed that "WebAssign homework was more helpful than the textbook homework." One student explained:

> There are more helpful tools on WebAssign than there is with me doing the homework on my own where all I have is my notes and the textbook to rely on. On WebAssign I can switch to a different question, or I can watch a video on how it's done, or I can go to the exact spot in the textbook as to where I can find the problem. So, it is better.

The overwhelming sentiments of the students (51 out of 56) were that they liked that "WebAssign immediately grades their homework" and 52 liked that "WebAssign showed them the step-by-step solution of a similar problem when they asked for help." The students' interviews corroborated those findings. One student said "WebAssign shows you an example of how a problem is done and then you learn from that and fix your mistakes; the instant feedback is great." Another student, commented:

> I like best that WebAssign tells you right away if the question you did is correct or incorrect and it also has practice examples so if you're unable to do the homework question, you can try the practice example and then attempt the actual homework question.

However, approximately 30% (17 out of 56) of students felt that the questions on WebAssign do not match the questions solved in class.

More than 42 (out of 56) of the students strongly agreed or somewhat agreed that SI enabled them to better understand the course content, become better mathematics problem solvers, and perform better on tests, thus improving their grades. Problem solving strategies and the use of index cards were emphasized in SI sessions. One student claimed, "I feel like it [SI session] was very helpful, and it helped me learn the material better and reinforced what I learned the day before." The majority of students (47 out of 56) believed that SI sessions were helpful and 45 of them agreed that the SI leader was available to assist them from the first week of classes which confirms one of the distinguishing features of SI. All the students interviewed agreed that SI sessions were helpful. One student said, "I think SI sessions are very helpful; they help us to solve and understanding the questions, and the SI leader is very helpful." Similarly, another student commented, "SI provides us with an extra resource from day 1, so in case we need to approach someone besides the professor."

Thirty-nine (out of fifty-six) students believed the time spent in SI sessions were worthwhile while forty-three agreed that they learned appropriate study strategies in SI sessions. Activities in SI sessions focused on notetaking, text reading, problem solving, and study habits. One student noted, "I found better ways of memorizing formulas and knowing when and where to use the correct formula in SI sessions." Another student had the same opinion: "I found recopying my notes after class helped me in understanding the course. This is something I learned from the SI leader." Approximately 75% (42 out of 56) of students believed SI sessions motivated them to study. Five out of fourteen students believed attending the SI sessions motivated them to get their schoolwork done. One student noted, "Sometimes I felt like I was slacking then I would go to SI sessions and realized I have to review my class notes and complete the homework in order to have questions for the next session."

Discussion

The purpose of Research Question 1 was to determine if there was a significant difference in metacognitive and resource management strategies (Rehearsal, Elaboration, Organization, Critical Thinking, Metacognitive Self-Regulation, Time and Study Environment, Effort Regulation and Help Seeking) between students in a class with SI/online homework and students in a traditional class. The MSLQ is designed to determine the cognitive and metacognitive strategies and resource management strategies of students. Based on the responses to the modified MSLQ, there were no statistically significant differences between students in a class with SI/online homework and students in a traditional class in seven out of eight sub-scales of metacognitive and resource management learning strategies. Recall that these seven strategies were metacognitive self-regulation, time and study environment, effort regulation, help seeking, rehearsal, organization, and critical thinking. However, students enrolled in the course with SI/online homework showed higher levels of elaboration learning strategies compared to the students who were not exposed to SI/online homework. This could be due to the fact that students with SI/online homework had more opportunities to relate new concepts with prior concepts/knowledge and exposure to more examples and practice. Students in the treatment group are required to attend SI sessions so maybe that can be a reason why they viewed their effort to study calculus as low. In a similar study, Peacock (2008) found that students in courses with SI had higher levels of organization skills.

The purpose of Research Question 2 was to investigate students' attitudes toward, and experience working with SI and online homework using WebAssign. Based on the survey results, more than 75% (42 out of 56) of the students agreed that attending SI sessions and/or doing online homework using WebAssign have helped them to understand the course better, improved their problem-solving skills, and be better prepared for tests which boosted their performance in the class. One student said "WebAssign is helpful. It helps me answer the question(s) and it helps me to understand the material better." When asked about SI sessions, she noted "The best part is it [SI session] reviews what we learned in the past and prepared us to do well in tests." McGivney-Burelle and Xue (2013) noted out-of-class time should be highly structured to best prepare students for in-class activities. WebAssign and SI sessions are designed to guide and support students as they are studying the course content. Results from the survey and interviews showed that the overwhelming majority of the students liked the extra resources, WebAssign and SI, available to them outside of class. SI sessions also emphasized appropriate study skills and strategies for succeeding in the course. The findings reinforced the use of WebAssign to improve students' metacognitive and study skills.

Casazza and Silverman (1996) stated that an effective teaching/learning process increases awareness of one's own thought processes and encourages the learner to gradually assume the responsibility for learning. Students are taking responsibility for their own learning when they are solving problems on WebAssign and are using the resources (videos, tutorials, and Practice another question) available to them whenever they need them. Some students also reach out to their instructors and/or SI leaders when they realized they need additional guidance and support. These behaviors enable students to be actively engaged in the course material and be aware of their own thought processes and learning.

Implications and Limitations

A study to determine if there is a significant difference in the test scores between students in a class with SI/online homework and students in a traditional class can be conducted. Also, additional research about the effects of SI and online homework on the metacognitive and study skills of students is needed with larger class sizes. An investigation of the qualifications and training of SI leaders for their role is also warranted.

Even though every student in the study answered the questionnaire and survey, it is difficult to say if they read and thought about each question thoroughly before answering it. Moreover, it is not always clear if they answered the question truthfully or if they chose the answer that was sociably acceptable. Students grades were also not analyzed in this study. Students' academic records were not available, and the groups were not created by a randomization process. Students from four intact sections of a first semester calculus were utilized. The validation of true group equivalence in the control and experimental groups was not possible due to the lack of students' prior academic records. Also, there were two instructors in the study. Instructor quality (knowledge, degrees, etc.) was not measured and may have influenced the academic achievement between the groups. Furthermore, the lack of thorough training of SI leaders could also be impacting the way they conduct their sessions. This study was conducted for one semester in one course at a single college. The small sample size limits claims of generalizability to larger population.

Conclusion

Due to technological advancements, educators need to adapt accordingly to these changes in order for the United States to retain its standing in the world economy. Educators should continue to search for ways to increase students' metacognition and study skills. Incorporating WebAssign and SI sessions into the calculus class may help students to take responsibility for their own learning. WebAssign and SI sessions are additional resources and support that are available to students outside of the classroom. Both are designed to give students immediate feedback on their homework and/or course material. Although the results from the modified MSLQ showed a significant difference between the elaboration learning strategies of students in the two groups, the effect size is small. According to the survey and interviews, most students showed support for the SI program and the online homework management system, WebAssign. This may represent another step towards developing students' metacognition and study skills in college calculus courses.

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Appendix A

Modified MSLQ: STUDY HABITS AND LEARNING SKILLS – A Truncated List

PLEASE RESPOND TO THE QUESTIONNAIRE AS ACCURATELY AS POSSIBLE, REFLECTING YOUR OWN ATTITUDES AND BEHAVIORS IN THIS COURSE.

5) Choose the reason(s) for taking this course.
- ☐ It is a required course for my major.
- ☐ It is an elective course which fits my schedule.
- ☐ It will improve my career prospects.
- ☐ It was recommended by someone.
- ☐ Content seems interesting.

6) How many courses are you taking this semester (including this course)?

☐ One ☐ Two ☐ Three ☐ Four ☐ Five or more

7) During class time I often miss important points because I'm thinking of other things.
- ☐ Strongly disagree
- ☐ Somewhat disagree
- ☐ Neither agree nor disagree
- ☐ Somewhat agree
- ☐ Strongly agree

7) When I become confused about something I'm reading or doing for this class, I go back and try to figure it out.
- ☐ Strongly disagree
- ☐ Somewhat disagree
- ☐ Neither agree nor disagree
- ☐ Somewhat agree
- ☐ Strongly agree

9) Before I study new course material thoroughly, I often skim it to see how it is organized.
- ☐ Strongly disagree
- ☐ Somewhat disagree
- ☐ Neither agree nor disagree
- ☐ Somewhat agree
- ☐ Strongly agree

10) I try to change the way I study in order to fit the course requirements and instructor's teaching style.
- ☐ Strongly disagree
- ☐ Somewhat disagree
- ☐ Neither agree nor disagree
- ☐ Somewhat agree
- ☐ Strongly agree

11) When studying for this class I try to determine which concepts I don't understand well.
- ☐ Strongly disagree
- ☐ Somewhat disagree
- ☐ Neither agree nor disagree
- ☐ Somewhat agree
- ☐ Strongly agree

12) If I get confused taking notes in class, I make sure I sort it out afterwards.
- ☐ Strongly disagree
- ☐ Somewhat disagree
- ☐ Neither agree nor disagree
- ☐ Somewhat agree
- ☐ Strongly agree

13) I usually study in a place where I can concentrate on my course work.
- ☐ Strongly disagree
- ☐ Somewhat disagree
- ☐ Neither agree nor disagree
- ☐ Somewhat agree
- ☐ Strongly agree

14) I make good use of my study time for this course.
- ☐ Strongly disagree
- ☐ Somewhat disagree
- ☐ Neither agree nor disagree
- ☐ Somewhat agree
- ☐ Strongly agree

15) I find it hard to stick to a study schedule.
- ☐ Strongly disagree
- ☐ Somewhat disagree
- ☐ Neither agree nor disagree
- ☐ Somewhat agree
- ☐ Strongly agree

16) I have a regular place set aside for studying.
- ☐ Strongly disagree
- ☐ Somewhat disagree
- ☐ Neither agree nor disagree
- ☐ Somewhat agree
- ☐ Strongly agree

17) I make sure I keep up with the weekly assignments for this course.
- ☐ Strongly disagree
- ☐ Somewhat disagree
- ☐ Neither agree nor disagree
- ☐ Somewhat agree
- ☐ Strongly agree