Qualitative and Quantitative Impact of Metacognitive Interventions in Supplemental Instruction Sessions

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Work-in Progress: Impact of Metacognitive Interventions in Supplemental Instruction Sessions

Abstract

This Work-in-Progress paper examines the impact of metacognitive interventions through Supplemental Instruction (SI) sessions, implemented at The University of Texas at Austin's first year engineering courses in fall 2019. After implementing two rounds of explicit metacognitive instruction in SI sessions over the length of the semester, we used a quantitative approach to assess differences in course grades and students' self-reported use of metacognitive strategies between SI and no-SI groups. Our analyses highlighted a statistically significant difference in course GPA and QDFW rates for SI attendees (students who attended 2 or more sessions) vs. non-SI attendees (students who attended 0 or 1 session). The difference was even more pronounced when breaking the groups down by SAT score categories, with the SI group outperforming their counterparts in all categories. When polling students on aspects of metacognition, we discovered that both SI and no SI groups had similar rates of awareness and use of "knowledge of cognition" strategies, yet SI groups had higher rates of awareness and use of "regulation of cognition" strategies. Thus, it is our interpretation that students using metacognitive strategies implicitly embedded in SI activities and SI Leaders conducting explicit instruction of course-specific metacognitive strategies contributed to the increase in the use of effective study strategies and therefore better course performance than those who did not attend SI.

Introduction

The Supplemental Instruction (SI) program is an internationally recognized academic support program created in 1973 at the University of Missouri in Kansas City and in the thirty years since its creation, the U.S. Department of Education have validated the claims that SI produces increased course grades, retention and graduation rates for regular attendees [1]. The SI sessions facilitate academic success by providing two regularly scheduled, voluntary, non-remedial sessions a week designed to combine review of difficult content and additional practice opportunities, and transferable study effectiveness skills to benefit students in all their coursework at the institution. The program uses a peer-assisted learning model where SI leaders, (undergraduates who have successfully completed the course, selected and trained in teaching and learning) offer sessions that incorporate collaborative learning strategies married with course material review.

Metacognition is broadly defined as knowledge and regulation of one's own learning. Several researchers have shown evidence for explicit instruction of metacognition and its benefits to student learning and outcomes ([2], [3], [4], [5], [6]). However, interventions that explicitly teach metacognitive practices to college students are lacking, with most research simply measuring metacognitive awareness and its link to achievement ([7], [8]). There is also some debate about

general metacognitive strategies [5] vs. disciplinary-specific metacognitive practices and instruction ([9], [10]).

A study conducted using modelling and coaching of discipline-specific metacognitive strategies in an introductory computer science course using peer tutors had significant impact on students' ability to apply knowledge to programming problems and also had long-term effects on students' future course outcomes [9]. Results from this article gave credence to the concept of teaching and training peer educators, such as tutors and SI Leaders to conduct metacognitive interventions in SI sessions to promote student learning.

The SI model was built upon theories including metacognition [11], and thus incorporates metacognitive practices. We also know the nature of the SI collaborative learning practices can improve students' use of effective study techniques [12]. However, there is little research on explicit instruction of metacognition in SI sessions. Therefore, we were interested in learning if explicit instruction of the SI model and its metacognitive underpinnings, as well as instruction on how to use metacognitive practices in their own study time would have an impact on students' awareness and use of metacognitive practices, as well as overall course grades.

The historically successful and evidence-based Supplemental Instruction (SI) program was introduced at The University of Texas at Austin in 2015 through a collaboration between the School of Engineering and the Sanger Learning Center. The supported courses include freshman level introductory courses in Electrical and Computer Engineering, and report high percentages of D's, F's, Q's (drops), and W's (withdraws). This report investigates the impact of explicit metacognitive training and lesson planning for SI Leaders and two rounds of explicit metacognitive instruction in SI sessions for these courses.

I. Motivation for Study

While most K-12 educators and administrators are trained to implicitly structure their instruction, class activities and assessments to ensure students make the most gains in learning, these are mostly conducted inside the classroom and without the conscious knowledge of these components on the part of the student. Since high school students are rarely explicitly taught the concept of metacognition and metacognitive strategies, when they arrive at many higher education institutions where these structures have been removed and expectations have shifted to self-directed learning outside of the classroom, initial struggle and sometimes failure become highly probable. Thus, one of the many goals of the SI model is to rectify the difficulties in transition that freshmen encounter by providing active practice of course review and study skill implementation.

As the SI program's effectiveness is assessed by aiming to reduce the DFWQ rates in first year engineering courses and in turn retain more students to the ECE program, we provide a more accurate reflection of the effects of SI by comparing students' grade outcomes using SAT scores as a gauge of preparedness. Over the course of implementing the SI program in EE 306 and EE

307E, we have endeavored to identify the components to emphasize that promote success while maintaining the authenticity of the SI model. This led us to explore the concept of explicit instruction of metacognitive practices in SI sessions. The SI model implicitly involves taking the theoretical underpinnings of metacognition and applying them in active and engaging SI strategies [11]. While SI programs across the world have shown positive impact, there is little research investigating the mechanisms of action that cause regular attendance to SI sessions and engagement in SI activities to improve course grades, retention and graduation rates. It is our hypothesis that metacognition might be one mechanism of impact for SI and our belief that explicit instruction of such strategies would improve on student performance and the transferability to students' overall success.

This report of the SI program's implementation of metacognitive instruction in SI sessions will detail our findings, which we hope will be beneficial for continued development of SI for this course, other engineering courses at the university and for other administrators of similar programs.

II. Limitations of Study

One limitation of determining correlations between grade outcomes and SI session attendance exists due to the voluntary nature of the program. By controlling for "preparedness" for college level coursework using SAT scores as a proxy, we can more accurately compare similar students to see the effects of SI attendance. However, there are many confounding factors that could impact grade outcomes, such as students' prior and current educational experiences, inequities in investment and resources in prior educational institutions, variations in help-seeking behaviors, intrinsic and extrinsic motivation and type of mindset. All of these factors and others make the connection of student performance to SI attendance difficult.

Another limitation with respect to the qualitative data is our use of self-reported survey data on their awareness and use of metacognitive strategies. While there are multiple study effectiveness surveys used to assess students' use of study skills, such as the LASSI, CSEI and MLSQ, in this study we used a shortened version of the Metacognitive Awareness Inventory (MAI) [5]. The MAI is an instrument that has been validated; Young and Fry [8] investigated the connection between MAI scores and course/overall GPA and found high correlations. They even advise it as a "... tool for professors to use to screen students in need of direct instruction related to metacognition" (pg.8). Therefore this limitation has been minimized and may provide instructional guidance for faculty and staff in the future. We collected survey responses for EE 306 students, but had extremely limited responses for EE 307E (a course with only 22 students), so we are only able to report on the metacognitive interventions in EE 306.

IV. Definitions Used in Study

The following terms utilized in this study are defined according to the authors' and the university's use:

- Q-Drop: students may leave a course after the 12th class day with a "Q" noted on their transcript [17].
- QDFW% rates: the percentage of students in the course who Q-dropped the class, made a D, F, or withdrew (and received a W on their transcript), in comparison to the whole student population for that course.
- SI group: students who attended 2 or more sessions; no-SI group: students who attended 1 or no sessions.
- MAI - Metacognitive Awareness Inventory [5]

Research Questions

To assess the impact of SI on freshmen engineering participants, this report addresses the following questions:
1] How does SI attendance affect overall course GPAs for students in EE 306 and EE 307E courses?
2] How does SI attendance affect QDFW% rates for students in EE 306 and EE 307E courses?
3] Is there any difference in self-reported awareness and use of metacognitive strategies between students who regularly attended SI sessions (where explicit instruction on metacognition and metacognitive strategies occurred) and students who did not attend SI sessions?

Design and Implementation

The SI program recruits, hires and trains undergraduate upper-class ECE students as SI leaders to conduct two identical SI sessions each week, using active and collaborative learning strategies. The SI Coordinator provides nine hours of pre-service training for SI leaders and then weekly training and development meetings (about one hour a week). These meetings provide the SI leaders with ongoing practice of facilitation skills, SI strategies, discussion of pedagogy and theory and continuous feedback. Regular observations are conducted by the SI coordinator and leaders conduct one peer observation per semester. The SI leaders are responsible for collecting attendance at each session and administering programmatic interventions throughout the semester.

The first step in implementing the metacognitive intervention was to properly introduce the concept and theory of metacognition and how it implicitly existed in the structure of SI. During the pre-service training, we recruited a renowned expert in metacognition (Dr. Veronica Yan, a faculty researcher at UT Austin) to conduct a personalized presentation to the SI Leaders. The talk included definitions of metacognition, effective strategies backed by evidence and research and in-depth discussion and explanation of SI strategies that were metacognitive in nature as well as how to instruct students on the use of the strategies.

The next component was integrating the use of metacognitive strategies in the SI Leaders' lesson plans. Leaders create their lesson plans the week before conducting sessions and submit them to

their graduate supervisor or SI Coordinator for feedback and revision. The lesson plan template for Fall 2019 was edited to include a section where Leaders were required to reflect on the strategies they chose and explain how it was contributing to improved metacognition for their students. Examples of these can be seen in the Appendix.

During every other weekly meeting, the SI Coordinator set aside time to check in about the metacognitive activities and any difficulties or issues implementing them. Twice in the semester, the SI Coordinator spent the one-hour meeting reviewing a Box folder with prepared resources on metacognition and worked with the Leaders to develop activities that explicitly instructed students in SI sessions on metacognition and what strategies they could effectively use in their own study time. The SI Coordinator continued to emphasize implementation of peer and collaborative activities inside SI sessions.

The SI Coordinator created the end of semester survey, including fourteen questions from the Metacognitive Awareness Inventory (MAI) [5], equally distributed between "Knowledge of Cognition" and "Regulation of Cognition", so as to get an accurate view of both students' awareness and use of certain types of metacognitive strategies.

Methodology

We collected both quantitative and qualitative data. In this study we use a quantitative approach to analyze the data and investigate the research questions detailed above. In future, we plan to use a mixed-methods approach by codifying qualitative survey responses for deeper analyses.

Two forms of quantitative data were collected:
SI Attendance: at the beginning of each session, students signed in with both their name and university unique identification number.
Grade Data: course letter grades and GPAs for all students enrolled in the course were collected.
Attendance data was documented by the SI leader at the start of each session and reported to the Learning Center, where the SI Coordinator maintained a database that connected with the university's registrar. The SI Coordinator collected additional data regarding student information such as limited demographics and SAT scores.

Students attending zero or one session were categorized as the *no SI group*, whereas repeat attendees (those attending two or more sessions) were categorized as the *SI group*. With this definition of the *SI group* as those who returned, the quantitative data focuses on the outcomes for students who considered SI a useful resource for repeated use versus those who did not. To examine the effects of SI on student academic performance, course grades were converted from nominal to ordinal data as per the university's numerical grade point equivalents.

Qualitative data was used to answer research questions about impact of SI on participating students and use of metacognitive strategy use by attendees and non-attendees. The method of qualitative data collection was by end-of-semester Qualtrics survey, administered to all students

enrolled in the courses. The survey comprised about 30 total questions (the number of questions differed on the survey depending on whether they attended or did not attend SI sessions regularly) and was administered on reading days before final exams. The survey collected students' names and university identifier numbers (self-entered) and then branched according to self-reported attendance to SI sessions. Both groups were asked to answer fourteen questions, which were a condensed version of the MAI and three open ended questions about how they dealt with difficulty in the course, what changes they would make in the future and what advice they would have for entering freshmen next year in the same course.

Findings

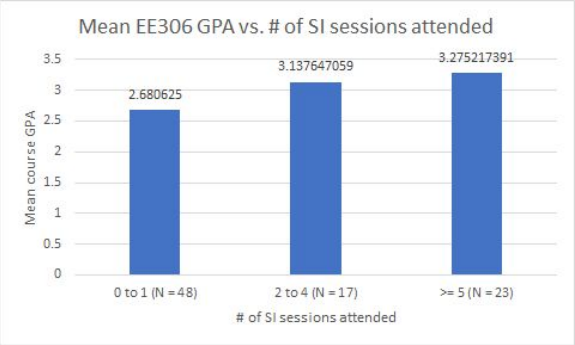

Figure 1. Mean GPA for SI and no-SI groups for EE 306, Fall 2019 t-test p value = 0.001196 (statistically significant)

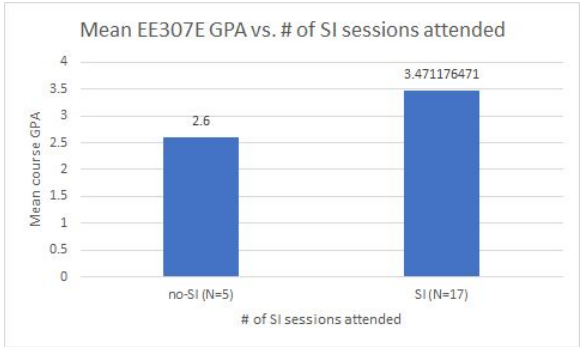

Figure 2. Mean GPA for SI and no-SI groups for EE 307E, Fall 2019 t-test p-value = 0.006281516321367 (statistically significant)

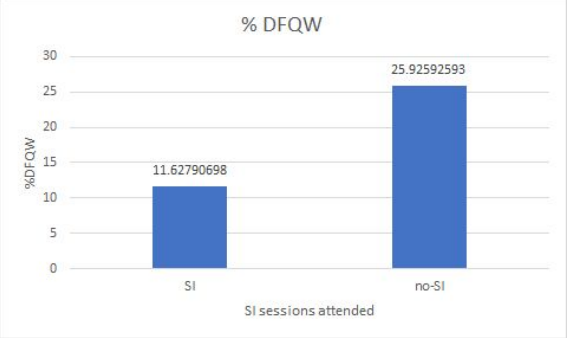

Figure 3. DFQW% rates for SI vs no-SI groups in EE 306, Fall 2019. Chi-square test p value = 0.077 (weak statistical significance)

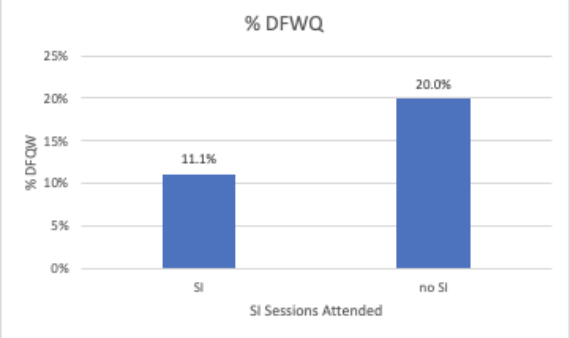

Figure 4. DFQW% rates for SI vs no-SI groups in EE 307E, Fall 2019

The data in Figures 1 and 2 show a statistically significant difference in course GPAs for the SI group vs the no SI group for both courses. Similarly, we see a smaller percentage of D's, F's, Q's and W's for the SI group vs the no SI group for both courses in Figures 3 and 4. For the EE 306 course, over 40% of the enrolled students attended regularly; EE 307E showed even higher rates of attendance, with 75% of enrolled students being in the SI group. These results mirror the data we have seen in past semesters for these courses and match what other programs have presented.

One criticism of accurately determining the impact of a voluntary support program like SI is the difficulty in extricating any self-selection bias. For example, highly prepared freshmen either use these services at higher rates or do not make use of any supports, yet still perform well in the course. Using one type of college prediction measure (SAT scores), all enrolled students in the two courses were divided into five groups, each with a 50-60 point range of SAT scores and then further subdivided by SI attendance to compare their course GPAs. Figures 5 and 6 show that in every SAT category, the SI group outperforms their no SI analogs for both EE 306 and EE 307E.

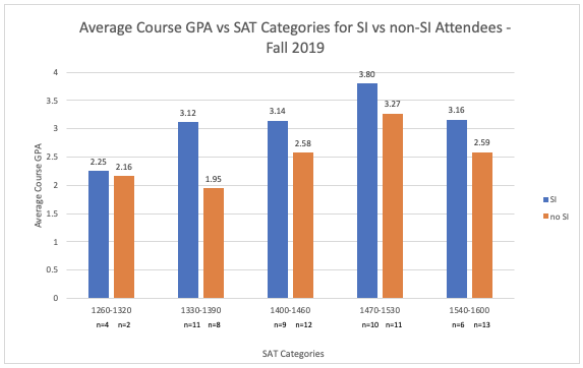

Figure 5. Average Course GPA vs SAT Categories for SI and no-SI groups for EE 306, Fall 2019

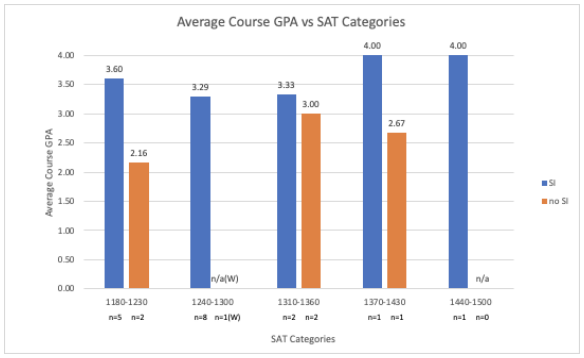

Figure 6. Average Course GPA vs SAT Categories for SI and no-SI groups in EE 307E, Fall 2019

With respect to our third research question, regarding the impact of SI sessions on student awareness and use of metacognitive strategies, we completed a variety of analyses. The MAI is divided into two parts, the "Knowledge of Cognition" section and the 'Regulation of Cognition" section. Each question is a statement and survey participants can answer "True" or "False". In the appendix, we present survey participants responses to questions from the MAI, comparing the SI and no SI groups.

We highlight the largest differences between the SI group and no SI group in regards to "Regulation of Cognition" responses in the graphs below. The SI group had much higher reported levels of use of "Information Management Strategies" (Figure 7) and "Evaluation Strategies" (Figure 8). This data confirms that while most students may be aware of effective strategies, putting them into action is another matter [13], and SI provides space and opportunity to learn how to apply these known strategies.

When we compared their self-reported expected end of semester course grade to their actual course grade, 88.89% of the SI group were able to accurately predict their course grade, vs 71.43 % of the no SI group (Figure 9, Appendix). Accurate self-assessment is an important measure of metacognition, so we are heartened by the possibility that SI positively impacts students' self-awareness. We found that respondents from both groups had similar levels of "Knowledge of Cognition" or metacognitive awareness (Figure 10, Appendix).

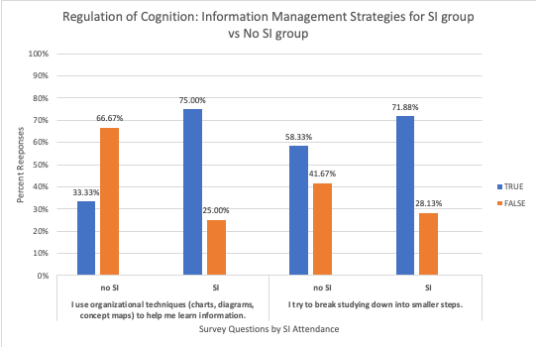

Figure 7. EE 306 survey responses for "Regulation of Cognition: Information Management Strategies" Questions from the MAI, SI vs no SI, Fall 2019

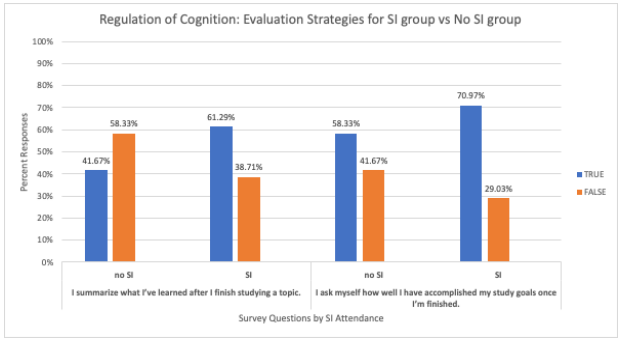

Figure 8. EE 306 survey responses for "Regulation of Cognition: Evaluation Strategies" Questions from the MAI, SI vs no SI, Fall 2019

Discussion and Summary

In this work-in-progress paper, we have outlined our methodology for embedding metacognitive instruction into SI sessions for two first year engineering courses and measuring the impacts to grade outcomes and use of effective study techniques. The course GPA for the SI group in EE 306 was 22% higher than that of the no-SI group. Similarly, the SI group in EE 307E made a 33% improvement in course GPA compared to the no-SI group. Comparing the %DFQW of the two groups for both courses also illustrates the tremendous impact that this program has had on passing rates.

The lesson plans listed in the Appendix highlight how the SI Leader for EE 306 used activities such as "Brain Dump" to prompt students to list all their study techniques, but also to evaluate those techniques for their effectiveness in actual deep learning, after some explicit instruction about metacognition by the Leader. In EE 307E, the SI Leader introduced Bloom's Taxonomy to students and spent time in the session having students differentiate their understanding of engineering concepts versus the application of that understanding to solving problems. While the MAI survey data indicated both groups showed a similar level of understanding of "Knowledge of Cognition", the SI group's report of higher "Regulation of Cognition", such as use of "Information Management Strategies" and "Evaluation Strategies" reflects what this group experienced and spent time practicing in SI sessions.

Thus, we interpret our data to indicate that students who regularly attended SI sessions learned about metacognitive strategies implicitly embedded in SI activities and received explicit instruction on course-specific metacognitive strategies and how to use them. This contributed to an increase in students' use of these effective study strategies in their own study time and therefore improved their course grades, compared to those who did not attend SI. We are encouraged by findings from this research and our future plans include administering the survey both at the start and end of the semester, to more accurately measure the impact of the SI program on student metacognitive awareness. We also plan to track student performance in future semesters as a way to measure transferability of skills learned in SI sessions.

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Appendix:

EE 306:

Qualitative Data

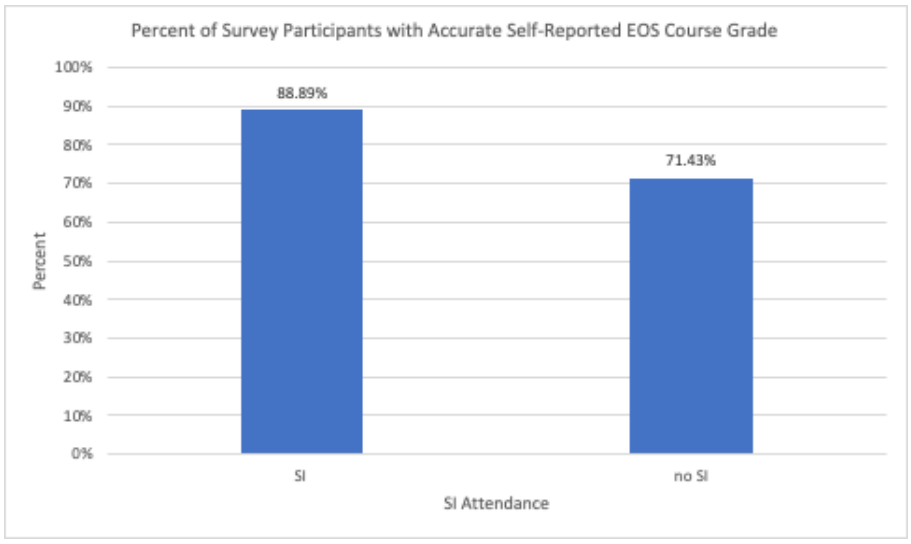

Figure 9. Percent of Survey Participants with Accurate Self-Reported EOS Course Grade, SI vs no SI, Fall 2019

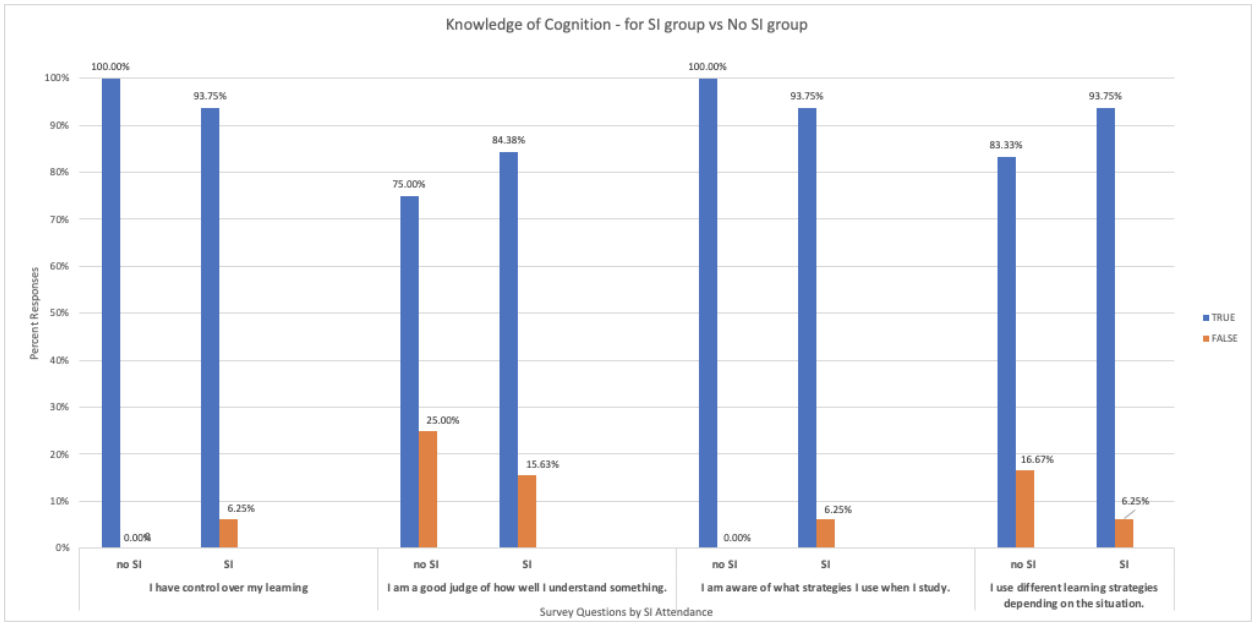

Figure 10. EE 306 survey responses for "Knowledge of Cognition" Questions from the MAI, SI vs no SI, Fall 2019

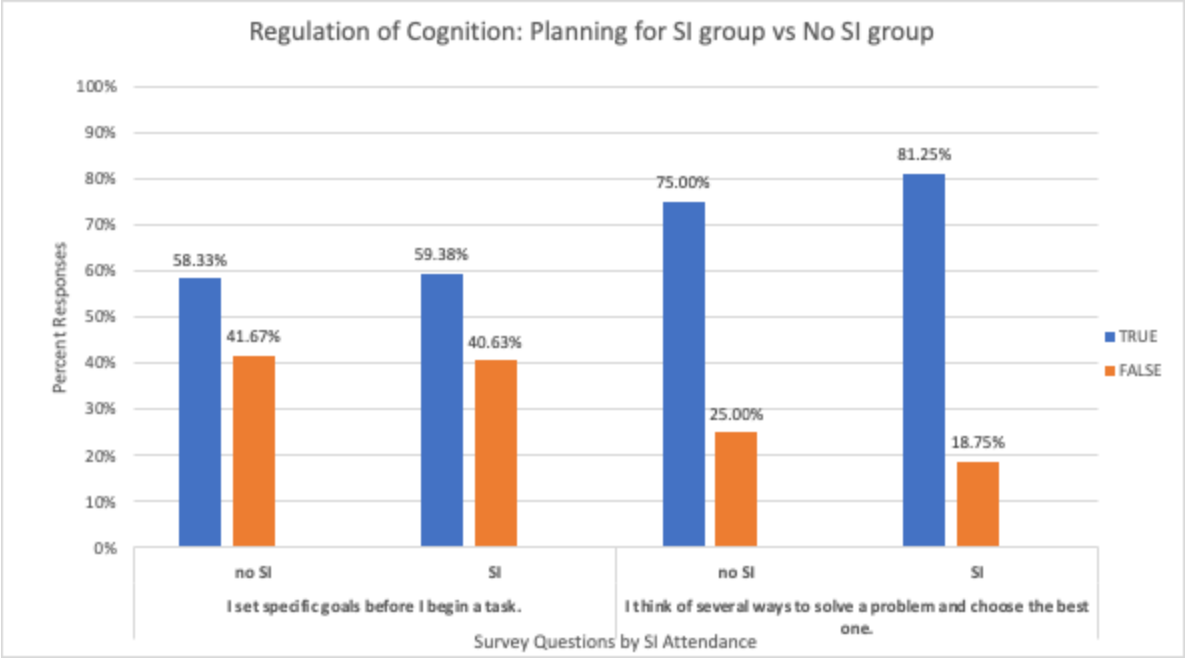

Figure 11. EE 306 survey responses for "Regulation of Cognition: Planning" Questions from the MAI, SI vs no SI, Fall 2019

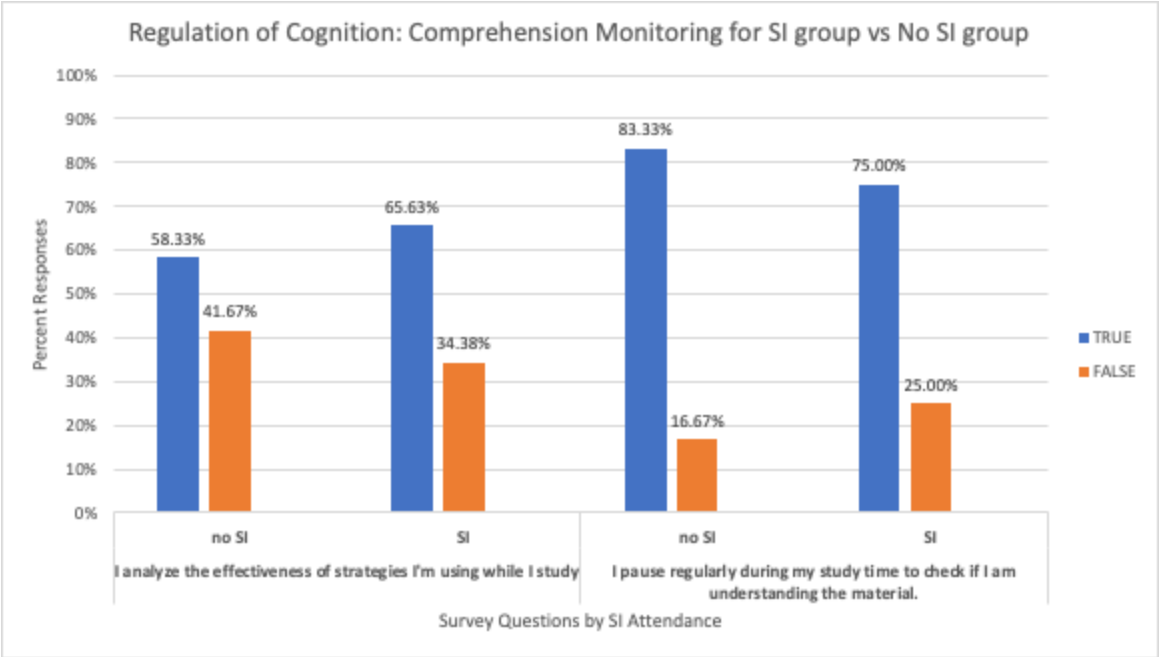

Figure 12. EE 306 survey responses for "Regulation of Cognition: Comprehension Monitoring" Questions from the MAI, SI vs no SI, Fall 2019

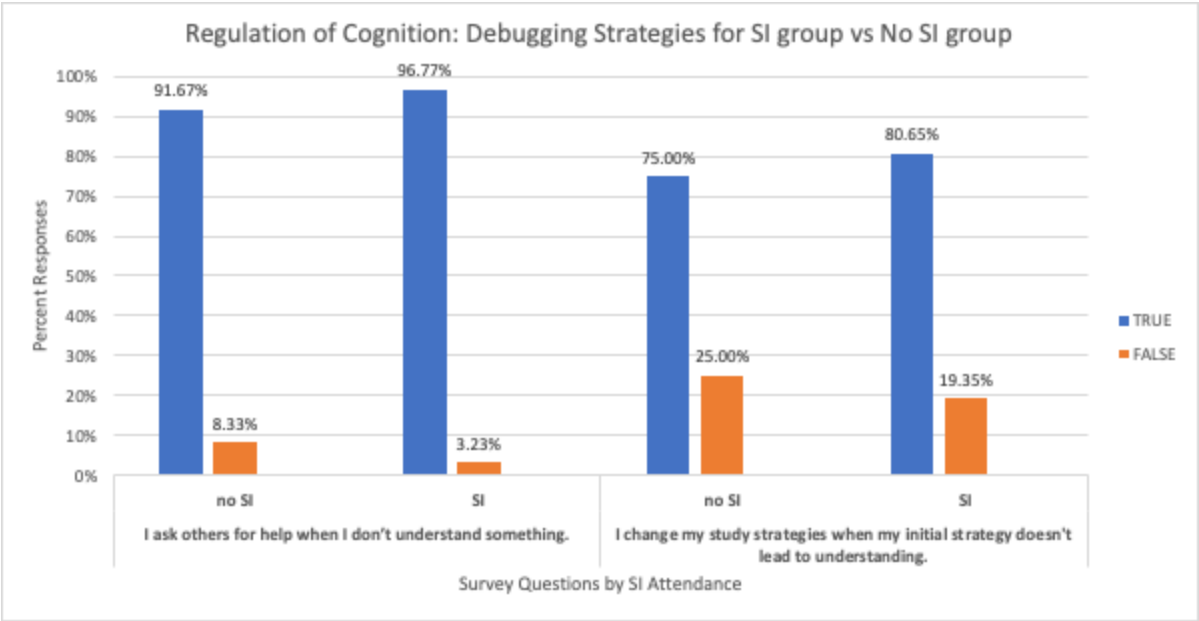

Figure 13. EE 306 survey responses for "Regulation of Cognition: Debugging Strategies" Questions from the MAI, SI vs no SI, Fall 2019

Excerpts from Lesson Plans for EE 306 and EE 307E with Metacognitive Activities, Fall 2019

EE 306:

SI Planning Sheet

Name	
Session Date	10-8-19 and 10-9-19
Course	EE306 – Introduction to Computing
Instructor	N. Telang

How will you incorporate one of these metacognitive strategies into your session?

Metacognitive Strategies	**Check which you are using**	**How will you pair this strategy with the activity? How will you discuss it with students?**
Spaced practice		The examples and problems incorporate concepts from earlier in the course; the students will be tasked with using the information they already know in conjunction with the new information.
Retrieval practice	X	
Elaboration		
Interleaving		
Concrete Examples	X	
Dual coding	X	

WARM-UP	Content to Cover	Collaborative Learning Technique	SI Strategy
15 minutes	Metacognition Strategies	Class Discussion/ Interactive Lecture	Brain Dump

Please provide a detailed breakdown of warm-up activity OR attach corresponding documents.

Have students "dump" all that they've learned throughout the semester on the board. This works well since they've recently taken their first exam. Have students also "dump" study strategies they used for the exam and used in general. Use this as a springboard to discuss metacognition. Emphasize strategies like interleaving and spaced practice as good study techniques, and discuss how past sessions have implemented metacognitive strategies.

SI Planning Sheet

Name	
Session Date	11-12-19 and 11-13-19
Course	EE306 – Introduction to Computing
Instructor	N. Telang

How will you incorporate one of these metacognitive strategies into your session?

Metacognitive Strategies	**Check which you are using**	**How will you pair this strategy with the activity? How will you discuss it with students?**
Spaced practice		Having them ask why their fellow students wrote code a certain way and building off of that will help solidify concepts of I/O. Additionally, the warm up will help students understand retrieval and metacognition better.
Retrieval practice	X	
Elaboration	X	
Interleaving		
Concrete Examples	X	
Dual coding		

WARM-UP	Content to Cover	Collaborative Learning Technique	SI Strategy
10 min	Metacognition	Class collaboration	Activity from Nisha's Powerpoint

Please provide a detailed breakdown of warm-up activity OR attach corresponding documents.

Give students each a slip of paper on the way in the door that says "Count the words with an 'E' or 'G' in them" or "count the words that make you feel good". Instruct students not to share what their paper says with anyone else. Then, read the list of words. Ask for the numbers they all got. Then, ask students to try and recall all the words in general. Use this as an intro into metacognition, and discuss the various techniques I use to structure sessions and how they can use them to study.

EE 307E:

SI Planning Sheet

Name	
Session Dates	10/7 and 10/11
Course	EE 307E
Instructor	Telang

How will you incorporate one of these metacognitive strategies into your session?

Metacognitive Strategies	**Check which you are using**	**How will you pair this strategy with the activity? How will you discuss it with students?**
Spaced practice		I will use the strategies of metacognition to allow students to think about how well they know the information
Retrieval practice	Yes	
Elaboration	Yes	
Interleaving		
Concrete Examples	Yes	
Dual coding	Yes	

Warm-Up:

Estimated Time (min.)	Content to Cover	SI Learning Strategy (LS)	Collaborative Learning Technique (CLT)
10 min	Bloom's Taxonomy	Card number 1	Clusters

Please provide a detailed breakdown of warm-up activity OR attach corresponding documents.

Put class into 6 groups and have them talk about what it means to have that level of understanding of the subject. We will discuss each one as a class and talk about how knowing how well you know a topic can lead to more success.

SI Planning Sheet

Name	
Session Dates	November 11th, 2019, November 15th, 2019
Course	EE 307E
Instructor	Dr. Telang

How will you incorporate one of these metacognitive strategies into your session?

Metacognitive Strategies	**Check which you are using**	**How will you pair this strategy with the activity? How will you discuss it with students?**
Spaced practice		The activity will be reviewing their tests and seeing their approach to the problems.
Retrieval practice		
Elaboration	Yes	
Interleaving		
Concrete Examples	Yes	
Dual coding		

Warm-Up:

Estimated Time (min.)	Content to Cover	SI Learning Strategy (LS)	Collaborative Learning Technique (CLT)
20 min	Test Overview	Bloom's Taxonomy	Think-Pair-Share

Please provide a detailed breakdown of warm-up activity OR attach corresponding documents.

I wanted to take extra time to tie their test back to metacognition. I wanted to specifically talk about how well they seemed to understand the material vs how well they did with that knowledge on the test. Have students talk to each other, and then share, parts of their test preparation technique that seemed to work well or not work as well as they hoped. To break the ice, I plan to open up about my experience with these topics and the problems I had while taking 307.