THE RELATIONSHIP BETWEEN CONFIDENCE, ACCURACY, AND DECISION MAKING IN A CALCULUS SKILLS REVIEW PROGRAM

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Just like physical skills, cognitive skills grow rusty over time unless they are regularly used and practiced so academic breaks can have negative consequences on student learning and success. The Keeping in School Shape (KiSS) program is an engaging, innovative, and cost-effective intervention that harnesses the benefits of retrieval practice by using technology to help students maintain proficiency over breaks from school by delivering a daily review problem via text message or email. A growth mindset is promoted through feedback messages encouraging students to try again if they get a problem wrong and to take on a challenge problem if they get a problem correct. This paper reports on the relationship between confidence, accuracy, and decision making during the implementation of the KiSS Program at a large university during winter break for students enrolled in an engineering introductory Calculus course sequence.

Keywords: Calculus, Metacognition, Technology, Undergraduate Education

Introduction and Theoretical Framing

Many Science, Technology, Engineering, and Mathematics (STEM) topics require proficiency in previously learned skills and concepts. Introductory STEM course sequences mimic this structure so that foundation courses feed into subsequent closely-related courses. Students finish the foundation course with skills and confidence that are critical to their success in the target course. However, this growth erodes in the time between the courses, especially if there is a prolonged gap in academic engagement such as a lengthy academic break (e.g., summer slide) (Cooper et al., 1996), or if the way students absorbed the information was not conducive to retention (e.g., stress-induced intentional forgetting) (Ramirez et al. 2017). In order to address this loss of proficiency, many faculty, departments, and institutions of higher education would like to see students engage with course content outside of class and during academic breaks. Regrettably, this is not likely to happen spontaneously, so the issue is how to reach students and prompt them, in a non-threatening way, to regularly review things that they have learned and need to maintain for future learning. One way of doing this is to deliver review opportunities, along with encouragement to confront deficiencies and meet potential, in a location that students are unlikely to miss, namely on their mobile phones or via email.

This paper discusses the implementation of an engaging, innovative and cost-effective program that uses technology to help students maintain proficiency over breaks from school, while also promoting a growth mindset (van de Sande, 2019a, 2019b). Theoretically, the Keeping in School Shape (KiSS) program draws on the well-documented benefits of regular retrieval practice, namely recalling previously material as an effective way of maintaining cognitive performance (Butler et al., 2014; Roediger & Butler, 2011; Rohrer & Pashler, 2007). The KiSS Program embodies retrieval practice by sending students a multiple-choice mathematics question daily via text messaging or email. The problems are chosen specifically to be skills that are requisite for success in the mathematics course following the break from school.

Retrieval practice delivered daily is also consistent with the growth mindset metaphor of the brain as a muscle that grows stronger with exercise (Yeager et al., 2019). Many students

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approach their studies convinced that intelligence is fixed, so those who have to put forth effort lack natural talent and the ability to succeed (Boaler 2010, 2013; Dweck, 2006). This failure to believe that, through effort, the brain can grow stronger negatively affects achievement (Boaler, 2013), especially for more underrepresented groups (Aronson et al., 2002; Blackwell et al, 2007). When students engage in retrieval practice by testing themselves regularly to see if they can perform a previously learned skill or concept, they are essentially flexing and toning their "brain muscle" and keeping it from atrophying with disuse. The design of the KiSS Program further promotes a growth mindset by including features such as hints, the option to attempt more challenging problems, and feedback messages that praise and encourage effort so that students have opportunities to see mistakes and difficult problems as profitable opportunities to engage in productive struggle.

Mindset not only plays a role in broad measures of math achievement and but can also influence how students behave in a specific problem-solving context (Shen, Miele, & Vasilyeva, 2016). Students with a fixed mindset are less likely to persevere in a challenging math task than students with a growth mindset, and also have lower confidence in their ability to do math after being confronted with challenging problems. Given that what counts as challenging is a subjective judgment, we use technology to explore the relationship between student confidence in the ability to perform a task and subsequent navigation through a review activity.

Methods

The KiSS program was designed to encourage students to regularly connect with their studies and to gauge their ability to perform previously learned material over break by providing easily accessible review opportunities for requisite skills. At the same time, the configuration of technology allowed us to unobtrusively collect information on confidence, accuracy, and decision making as students engaged with the review activities.

Context

Each problem in the KiSS program was designed as an independent Qualtrics (https://www.qualtrics.com/) survey since Qualtrics allows surveys to be distributed as sms messages or emails. Figure 1 shows a schematic of how the daily problem link was pushed to students' phones as a text message or sent to their email addresses. Clicking on the link took students directly to the daily question survey. Before attempting the daily review problem, students were first asked to use a 5-point scale (ranging from "not at all" to "Super Duper") to show how confident they were that they could answer it correctly. Informal rating labels and accompanying emojis were used in an effort to make this self-assessment less threatening.

After that, as shown in Figure 2 which depicts a flowchart of the regular daily agenda, students responded to the question by selecting one of the answer options, which opened up a sequence of possible paths and opportunities. On certain days of the week, the agenda included additional paths (not shown here): On Tuesdays (aka "2's-days"), students could choose to do an additional problem and on Sundays (aka "Trivia Days") students could choose to do the daily calculus problem followed by a calculus trivia question or just respond to the trivia question. Figure 3 depicts the opportunities for engagement that stem from getting the daily problem incorrect, namely getting a hint and trying again (encouraged), seeing the solution, or exiting. Students who got the daily problem correct had the option of trying a related more challenging problem (encouraged), seeing the solution, or exiting. Whether they got the daily review problem incorrect or correct, students were prompted with messaging to adopt a growth mindset by persisting ("Let's rethink this!") or pushing themselves ("Let's push ourselves!").

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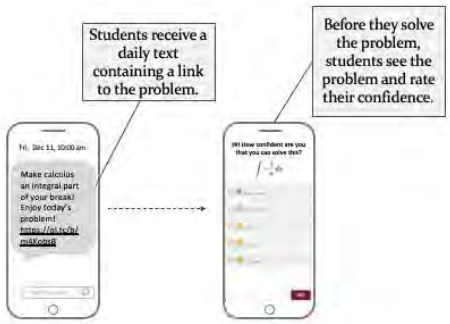

Figure 1: Schematic of review problem delivery and confidence rating

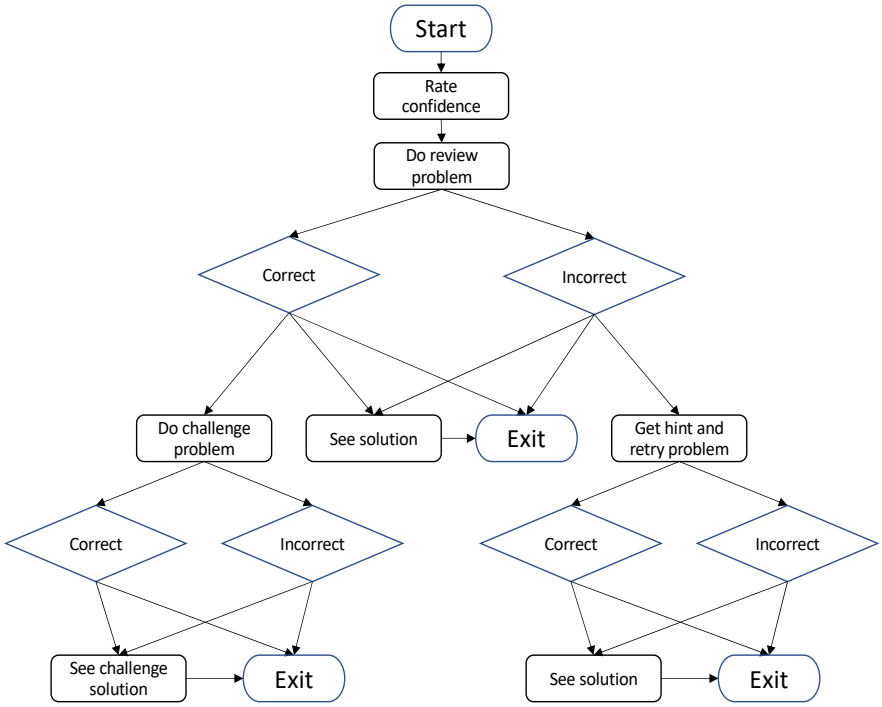

Figure 2: Flowchart showing various paths and opportunities within the daily review

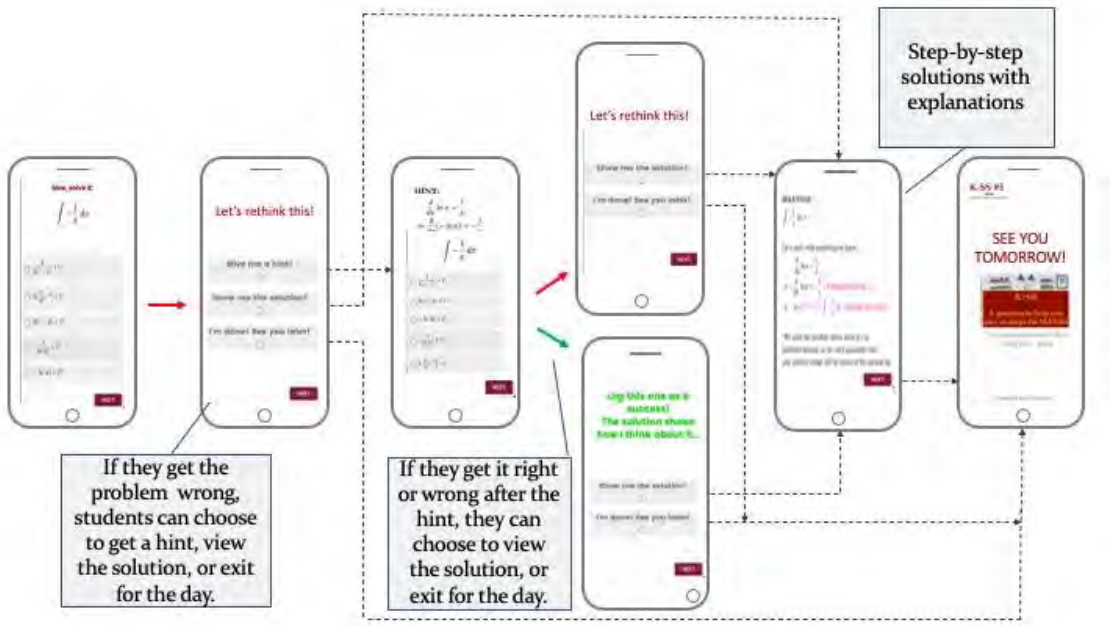

Figure 3: Schematic of possible paths following an incorrect response

Participants

This paper reports on select results from an implementation of the KiSS Program at a large university in the Southwest for students who were enrolled in an introductory Calculus course sequence for engineers. The program was designed for students who had successfully completed the first course of the sequence and were planning on taking the second course in the upcoming spring semester. At the end of the fall semester, students who were enrolled in the second course in the following spring semester were invited to participate in the KiSS Program over winter break via email notifications and posts by instructors on course websites. Students who responded by texting a self-selected code name were enrolled in the program and received a problem daily (with the exception of holidays) for each of the 33 days of break. 357 students signed up to participate in the KiSS Program, and 307 of these opened at least one of the 33 problems.

Data Collection

On any given day of the program, students could choose whether or not to respond to the daily problem and could also exit the daily problem at any stage (e.g., after rating their confidence but before answering the problem). The following data was logged for each participant who opened the daily problem: time and duration of participation, confidence rating (for the daily problem), answer choice, and problem path (e.g., whether or not they accessed the hint, viewed the solution, or opted for a more challenging problem). Answer choice and resource use was also logged for any second attempts at the daily problem following hint use, as well as for any challenge problem attempts. In an effort to engage students in the KiSS Program as a fun review tool (rather than as a research study), demographic data was not collected prior to participation. Data from entrance and exit surveys, along with more in-depth interviews on program experience are discussed elsewhere (author2 and author 1, 2021).

Results

In this paper, we report on how student confidence relates to performance and engagement in the program on a daily basis. In particular, we look at relationships between confidence and accuracy, and how confidence in the ability to solve the daily problem plays out in the decisions students make for navigating through the review activity.

Confidence Ratings

Figure 4 shows the percentage of confidence ratings of each level (n=5273). Students were generally very confident in their ability to be able to solve the daily problem, with 73% of the ratings being either "somewhat" or "super duper!" Although self-selection in KiSS Program participation may play something of a role, this skew towards higher levels of confidence is also not surprising since all of the daily problems were a review of fundamental skills learned in or prior to the course that students had just successfully completed (Calculus 1).

Confidence Phrases and Emojis	not at all!	not very	meh	somewhat	super duper!
Percentage	5%	8%	14%	26%	47%

Figure 4: Percentage of confidence ratings of each level

Confidence and Accuracy

After rating their confidence, students were presented with the daily multiple-choice problem. Figure 5 shows the relationship between accuracy and level of confidence. As can be seen, there was a positive relationship between accuracy and confidence. In addition, although there were very few times when a student did not respond to the problem after having rated their confidence, these were all instances in which the student had low or very low confidence in their ability to solve the problem, even just by selecting an option from five possible answers.

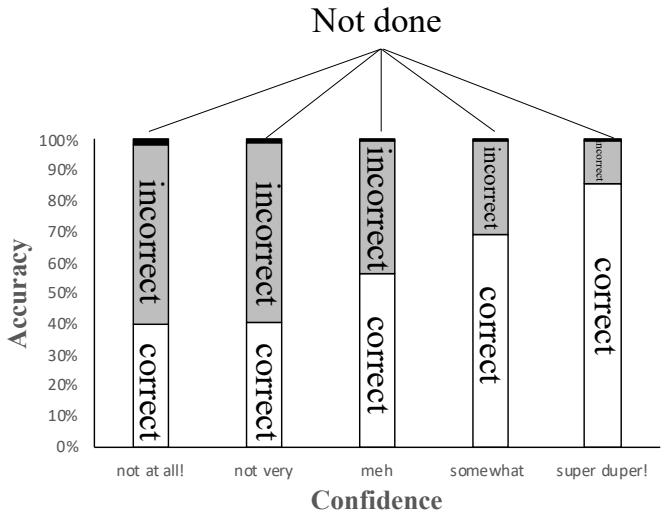

Figure 5: Accuracy of First Attempt on Daily Problem by Confidence (n=5273)

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Accuracy and Path

After rating their confidence on their ability to solve the daily problem, students could take various paths through the daily review depending on their accuracy. Students who got the problem correct could choose to do a related challenge problem, view the solution to the daily problem, or simply exit for the day. Students who got the problem incorrect could choose to view a hint and retry the problem, view the solution, or exit. As can be seen in Figure 6 (left), for students who got the initial daily problem correct, confidence was related to the likelihood of engaging in a challenge problem afterwards. Students who were more confident in their ability to solve the initial problem were more likely to opt for a more challenging problem. Students who got the initial problem wrong (right), however, tended to choose to retry a problem, regardless of their confidence. Figure 6 also shows that exiting was more prevalent for students after getting the initial problem correct rather than incorrect, and that, in general, higher versus lower confidence was more characteristic of exiting the program for the day.

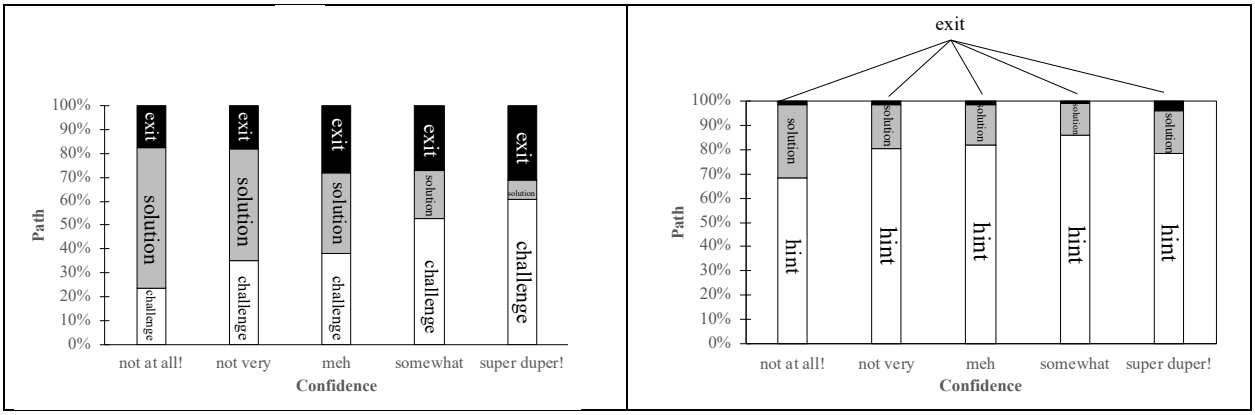

Figure 6: Path Taken by Students Who Got the Daily Problem Correct (left: n=3757) and Incorrect (right: n=1487)

Accuracy Following Challenge and Second Attempt

Depending on whether or not a student got the initial daily problem correct, they had the option to do a challenge problem or view a hint and retry the problem. Figure 7 depicts the relationship between confidence in being able to solve the initial problem and accuracy of the challenge problem (left) and accuracy of the second attempt of the initial problem (right). As seen in Figure 7 (left), confidence in being able to solve the initial problem was positively related to accuracy on the related challenge problem. However, for students who got the initial problem incorrect and then tried it a second time, the hints were helpful regardless of confidence (Figure 7, right). In addition, very few students changed their mind and exited for the day after choosing to view a challenge problem or a hint. However, these instances tended to occur more for students with low confidence who indicated that they wished to try a challenge problem after correctly solving the daily problem.

Path Following Second Attempt

Students who got the initial daily problem incorrect and chose to view a hint then had a second chance to attempt the problem. Whether or not they got the problem correct on this second attempt, students could choose to view the solution or exit for the day. As shown in Figure 8 (left), initial confidence was negatively related to viewing the solution for students who got the problem correct on their second attempt. More confidence initially, even though they got

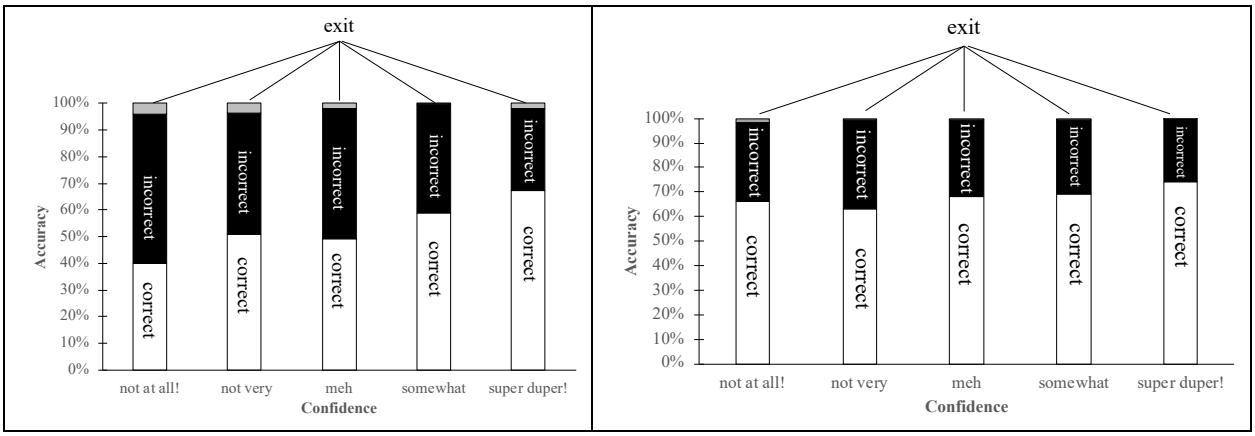

Figure 7: Accuracy on Challenge (left: n=2028) and Second Attempt of Daily Problem (right: n=1202) by Initial Confidence

the problem incorrect on the first attempt, was more associated with exiting, rather than viewing the solution, whereas less confidence initially was more associated with viewing the solution, even though the second attempt at solving the problem was successful. However, students who got the problem incorrect on their second attempt, regardless of their initial level of confidence, almost always chose to view the solution before exiting. As on the first attempt at the problem (Figure 6), exiting was much more characteristic of students after a successful versus an unsuccessful second attempt.

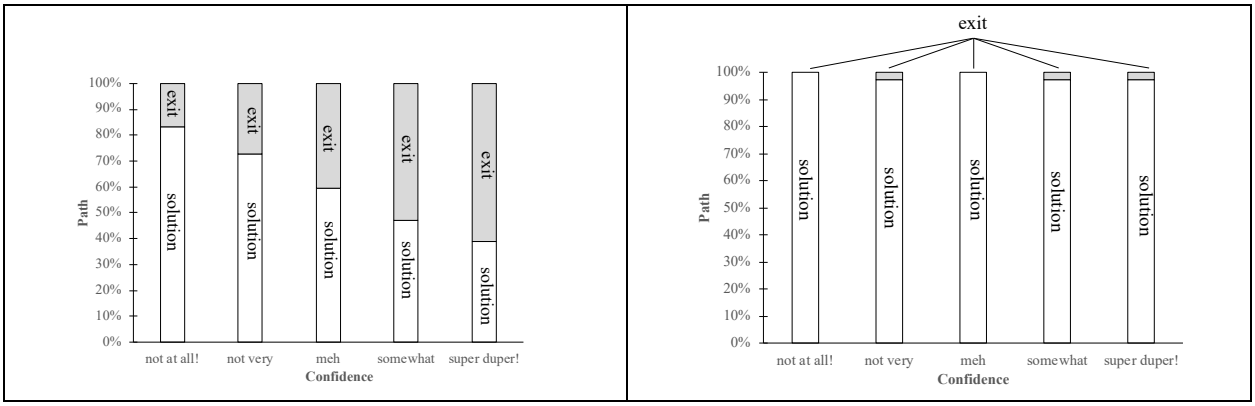

Figure 8: Path Taken by Students Who Got the Second Attempt of the Daily Problem Correct (left: n=827) and Incorrect (right: n=367) by Initial Confidence

Path Following Challenge

Students who got the initial daily problem correct could elect to do a second related challenge problem. Whether or not they got this more challenging problem correct, students could choose to view the solution or exit for the day. As seen in Figure 9 (left) initial confidence was negatively related to viewing the solution for students who got the challenge problem correct to some extent. Students who were unsure of their ability to solve the initial problem were more likely to look at the solution after getting both the initial and the challenge problem correct. This tendency was much more marked for students who got the challenge problem incorrect. Students who lacked confidence in their ability to solve the initial problem and then were unable to

correctly solve the challenge problem almost always viewed the challenge problem solution. As on the first and second attempts at the problem (Figure 6 and 8), exiting was more characteristic of students after a successful versus an unsuccessful attempt.

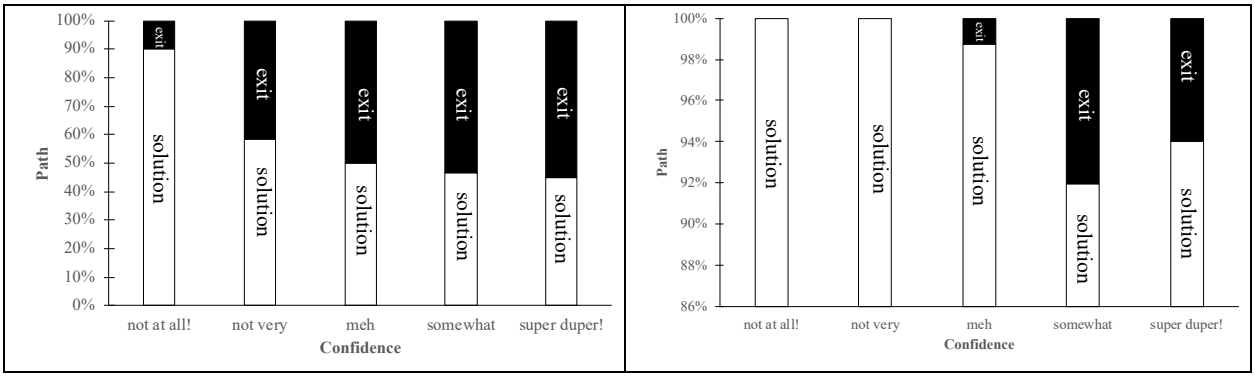

Figure 9: Path Taken by Students Who Got the Challenge Problem Correct (left: n=1243) and Incorrect (right: n=723) by Confidence on Daily Problem

Discussion

The KiSS Program illustrates the use of technology to engage students in productive struggle outside of the classroom during academic breaks. Since most students would otherwise not be testing themselves daily, the amount of voluntary participation is quite promising and could presumably be increased with more sophisticated and targeted marketing efforts. Also, the low exit rates after opening and engaging with the daily review activities indicate that the KiSS Program is successful at capturing student interest. The KiSS program therefore addresses the challenge of getting students to participate in beneficial regular retrieval practice (Kallookaran & Robra-Bissantz, 2017), even during breaks from formal instruction.

Implementing the KiSS Program and collecting judgments of learning (Rhodes, 2016) allowed us to explore metacognitive monitoring or metacomprehension (Dunlosky & Lipko, 2007) in an authentic setting. In particular, we were able to trace the relationship between confidence in the ability to solve a review problem and accuracy on that problem, as well as on a related more challenging problem. This use of technology also gave us insight into the role confidence plays on help seeking, although it did not provide a detailed account of how students used the various program resources.

Reaching students, especially those that are vulnerable, and helping them feel connected to their instructors and to their studies in a normal and predictable fashion is especially critical in light of unexpected disruptions, such as the recent pandemic, when students are overcome with feelings of alienation, uncertainty, and anxiety (Dziech, 2020). Therefore, the study of how technology can be used to deliver regular review opportunities outside of class, while simultaneously framing a positive mindset, is particularly timely and warrants attention and exploration. The tracing of the relationship between confidence, accuracy, and decision making in the KiSS Program sets the stage for future work to investigate the ways in which students use review program resources, how particular classes of problems affect student confidence, and how we can design popular and accessible review programs to build confidence and help students realize their full potential as they prepare for their future studies and careers.

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