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Keeping in School Shape (KiSS): A Program for Rehearsing Math Skills over Breaks from School

Carla C. van de Sande*

School of Mathematical and Statistical Sciences, Arizona State University, United States

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ABSTRACT

If you don't use it, you lose it. School breaks, during which students do not regularly participate in instruction, can therefore have negative consequences on learning. This is especially true for mathematics learning since skills build progressively on earlier materials. How can we bridge these gaps in formal instruction? The Keeping in School Shape (KiSS) program is a mobile, engaging, innovative, and cost-effective way of using technology to help students who have time off between related math courses stay fresh on prerequisite knowledge and skills. Founded on learning theory and designed on a model of behavioral change, the KiSS program embodies retrieval practice and nudges by sending students a daily multiple-choice review problem via text messaging over school break. After rating their confidence in solving the daily problem students receive feedback and a solution. This study explores measures of participation, accuracy, and confidence in an implementation of the KiSS program over winter break between two sequential introductory engineering courses at a large state university in the Southwest United States. Results indicate that careful attention should be paid to the construction of the first few days of the program, and that encouragement, additional resources for review and practice, and an increased breadth of problem difficulty may improve participation.

1. Introduction

Just like physical skills, cognitive skills grow rusty over time unless they are regularly used and practiced. This means that school breaks when students do not regularly participate in instruction can have negative consequences for learning. For instance, by a conservative estimate, summer vacation sets K-12 students back by one month of instruction; that is, it causes them to lose one month of grade-level equivalent skills relative to national norms^[1]. Although this “summer gap” effect or “slide” has been documented for many

school subjects, it is most pronounced for mathematics which requires a strong foundation of prior knowledge. And the loss of academic ground following time off from school extends into higher education too. We now know that having breaks between sequential closely related mathematics courses significantly lowers performance in the second course at the university level^[2]. How can we bridge the gap between courses and stem the loss of learning over school breaks for students in higher education who have busy lives and do not wish to spend their breaks from school studying and preparing for

*Corresponding Author:

Carla C. van de Sande,

Associate Professor, School of Mathematical and Statistical Sciences, Arizona State University, United States;

Email: carla.vandesande@asu.edu.

the upcoming semester? The Keeping in School Shape (KiSS) program was developed by the author as a mobile, engaging, innovative, and cost-effective way of meeting this need that is grounded in theories of learning and behavior. This paper describes the design, theoretical underpinnings, and implementation of the KiSS program as it was used to help university students transition between two sequential mathematics courses over winter break from university. In particular, patterns of participation and confidence ratings are examined to shed light on the potential of the KiSS program to address loss of learning over breaks in formal instruction by providing students with convenient opportunities to regularly rehearse previously learned material.

2. The Design of the KiSS Program

Figure 1 provides an overview of the design and delivery of the KiSS program. Each day over the break from school, a free bulk messaging script on Google Voice was used to send students a daily text message containing a link to an online quiz site (<https://www.flexiquiz.com/Home/Index>) where the problem of the day was found. Before seeing the problem, students chose one of five good causes that they wished to support if they answered the daily problem correctly. Next, students were shown the daily problem and asked to rate their confidence in being able to solve it correctly. They selected from five levels of confidence ranging from “not at all confident” to “very confident,” and each of the options was accompanied by a corresponding emoji. After rating their confidence, students solved the problem and responded by choosing one of five possible answers. Correct responses were rewarded with a positive, encouraging message, such as “Great job!” or “Extraordinary!” Both incorrect and correct responses were followed by a link to a video solution since viewing a solution is beneficial for learning regardless of accuracy [3]. The problems stayed open for 24 hours before being replaced by the next daily problem.

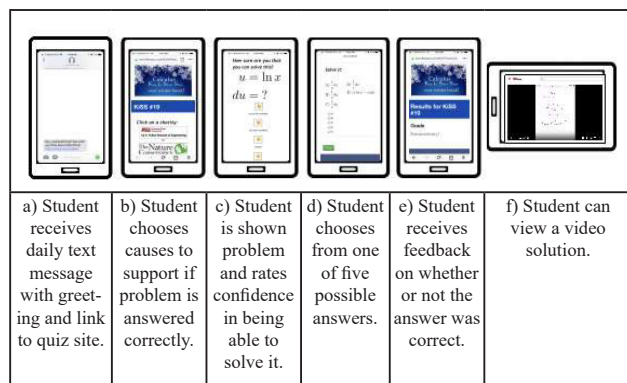


Figure 1. The KiSS program from daily text message to problem solution

The KiSS program was deliberately designed to fit into a student-centered education ecosystem [4] and as an activity that would appeal to university students. Design decisions regarding content, delivery, and visibility therefore reflect steps that were taken to limit time commitment and guard against infringement on other priorities in students’ lives. First, regarding the KiSS program content, the decision was made to construct the problems as multiple-choice items. This feature saves students both time and frustration by preventing students from having to laboriously type in involved mathematical expressions as their solutions and possibly make typographical errors (e.g., forgetting to pair up parentheses).

Another feature of the KiSS program is that it was delivered via text messaging. The intended audience for this implementation of the KiSS program consisted of young adults in their first or second year at university. Using text messaging facilitated broad general access since 92% of Millennials own a smartphone (85% for Gen Xers) [5], and smartphones are the primary means of online access for younger adults, non-whites, and lower-income Americans [6]. Furthermore, texting is aligned with the goal of being student-centered [7] since the KiSS program is then essentially at a student’s fingertips whenever they choose to engage with it.

The KiSS program was also designed to reduce feelings of math anxiety and exposure. One reason that students suffer from math anxiety is that they have a gap, or “dropped stitch,” in their prior mathematics learning [8]. Being confronted with a daily problem from material that a student has supposedly mastered and is expected to have retained for future learning might well trigger math anxiety in some students. Therefore, the KiSS program provided solutions to the problems to help refresh memory of relevant skills and concepts, and also allowed students in the program to cloak their visibility through participation using self-selected code names.

The student-centered nature of the KiSS program is further evident in the way that students were encouraged to participate. In addition to the intrinsic motivator of staying fresh on relevant skills and concepts, the KiSS program includes charitable giving as an incentive. This design decision reflects the characteristics, priorities, and ideals of the student audience, which is on the cusp of two generations, “millennials” (born roughly from 1980–2000) and the following generation known as “Generation Z” (born roughly from 1995–2010). Both of these generations have a reputation for being tech-savvy and generous. For instance, a survey of more than 35,000 millennials revealed that 52% were interested in monthly

giving, and 85% were motivated to give by a compelling mission or cause^[9]. Similarly, Generation Z members have been dubbed “philanthroteens” since 32% of UK and US Generation Z members surveyed reported having already donated money^[10]. Therefore, before answering the daily KiSS problem, students were asked to choose one of five good causes that would receive a point if they answered correctly. Four of the causes were non-profit organizations (spanning scientific research, humanitarian aid, nature conservation, and animal protection) and one was a university scholarship fund. At the end of the program, the cause with the largest number of points received that amount in dollars.¹

Each of these pragmatic design decisions was made so that students could have opportunities to regularly and conveniently practice previously learned skills and concepts over breaks from formal instruction. The inspiration for providing these opportunities in this way has been rooted in theories of learning and behavior.

3. Theoretical Framework

“If you don’t use it, you lose it” is the sad reality of what happens if skills are not used for lengthy periods of time. Therefore, it makes sense that a solution to losing ground over breaks from school lies in providing students with noticeable opportunities to regularly use what they have learned and need to retain when they are not in school. Daily problems delivered to students via text messages are one way of meeting this need since they serve as attention-grabbing prompts, or nudges, to retrieve previously learned materials. Theories explaining the benefits of retrieval practice are related to memory enhancement, and nudges are recognized as an effective way of bringing about behavioral change.

3.1 Retrieval Practice

The benefits of taking a memory test, or retrieval practice, have been repeatedly documented in both laboratory settings and in classrooms^[11,12]. Retrieval practice leads to flexible understanding, improves higher order thinking skills, and promotes knowledge transfer by making apparent to students what they have and have not mastered^[13]. A central idea of retrieval practice is that testing can be used as a study resource. Although testing is usually thought of as a neutral activity (one that allows learning outcomes to be measured), there is now substantial evidence supporting the fact that taking a test usually enhances later performance on the material relative to rereading it or to having no re-exposure at all^[14]. This phenomenon

has been dubbed the “testing effect”^[15]. In essence, testing provides students with retrieval practice opportunities that have been shown to be beneficial not only for retaining information, but also for knowledge transfer^[16-18].

Theoretical explanations for the texting effect focus on how retrieval practice affects memory. For instance, it has been posited that retrieval practice leads to the elaboration of existing memory traces or the creation of additional retrieval paths, thereby making future retrieval of information more likely^[19-21]. In a related vein of thought, the act of retrieval practice constitutes an effortful recall of information and increased reprocessing of memory traces to benefit long-term retention of the information^[22,23]. Thus, the general idea is that testing can be a valuable study technique because it solidifies memories which is precisely what is needed to help stem learning loss over breaks from formal instruction. A model of behavioral change speaks to why daily texting is the best way to get students to engage in memory testing.

3.2 Nudges

Just a brief amount of helpful information delivered in a visible and timely manner can promote a certain behavior. The power of such “nudges”^[24] has been well established in contexts that range from personal lifestyle issues^[25] to major life decisions^[26] advice, support, and reminders^[27,28], especially to at-risk populations^[29,30]. Although nudges can come from many sources (e.g., public announcements), nudges from an interested party can not only lead to changed behaviors but can also build key relationships. Most directly relevant for the purpose of designing the KiSS program, nudges from instructors have shown promise for increasing student engagement^[31] and preventing summer learning loss of literacy skills^[32]. Potential KiSS program participants were aware through recruitment materials that the KiSS program was designed and delivered by an instructor (the author) at their university. The underlying message was that a faculty member cared about their future success since formal and informal faculty-student interactions that reinforce and extend intellectual goals and purposes have been repeatedly linked to enhanced student learning^[33-37], particularly for freshman^[38]. Furthermore, conceptualizing the KiSS program as a “nudge campaign” makes sense because the delivery of nudges in the form of text messages has been shown to be effective for reaching college students^[28].

4. Methodology

This is an observational study in the sense that participants were volunteers who were not assigned to any treatment condition. For each participant, the dates and timing of participation, charitable giving selection, confidence

¹ The author supplied the funds for this study. However, as the KiSS program is scaled up to include more participants, one idea is to solicit sponsors who agree to donate funds for each correct answer to the causes chosen by their sponsored student(s).

ratings, and response to each problem were collected on the online quiz site for descriptive analysis. These measures provided insight into participation, accuracy, and confidence over the implementation of the KiSS program.

4.1 Participants

The KiSS program was implemented over winter break at a large university in the Southwest United States between two sequential mathematics courses, so participants had just completed the first course in the Introductory Engineering Calculus sequence during the fall semester and were planning on enrolling in the second course in the sequence in the upcoming spring semester following the break. The KiSS program ran for 25 consecutive days when the university was not in session for winter break, excluding two major holidays (Christmas Day and New Year’s Day) during that time period. Students were recruited by fliers (Figure 2) delivered to several classrooms (different sections of the first course in the sequence) during the last week of classes before winter break began. If they wished to enroll in the KiSS program, students texted a self-selected code name to the KiSS program number that was printed on the flier. In addition to protecting student identity, these unique code names allowed the author to track each student’s activity throughout the KiSS program. All students were at least 18 years of age and consented to participate before viewing their first daily problem. Students were also informed that they could end their participation in the program at any time without any penalty or negative consequences. In the interest of promoting the perception of the KiSS program as a review resource (rather than as a research study), no demographic information was collected.



Figure 2. KiSS program advertisement flier

4.2 Materials

Mathematics builds on prior knowledge, and many problems in mathematics require fluency with previously learned material. For instance, when students are learning multi-digit multiplication, they need to be able to readily recall their addition facts and how to add multi-digit

numbers, both skills which were taught in prior years. The same is true for the Introductory Engineering Calculus course sequence; many problems in the second course require fluency with material taught in the first course. Therefore, each of the 25 problems in the winter break KiSS program was included because it represented a skill that students need to retain in order to solve problems in the second course in the sequence. There were roughly three major topics covered in the winter break KiSS program, namely integration, differentiation, and limits. Within each of these topic areas, problems were selected based on the author’s extensive familiarity with the second course in the sequence and the skills from the first course that students often had trouble recognizing or recalling (e.g., the chain rule). Examples of KiSS problems are shown in Figure 3.

$\int (3 + 4 \sin \theta - 2 \cos \theta) d\theta$	$\frac{d}{dx} \cos(4x)$	$\lim_{t \rightarrow \infty} -e^{-t^2}$
A) $-4 \cos \theta - 2 \sin \theta + C$	A) $-4 \sin(4x)$	A) ∞
B) $4 \cos \theta + 2 \sin \theta + C$	B) $4 \sin(4x)$	B) $-\frac{1}{\infty}$
C) $3\theta - 4 \cos \theta - 2 \sin \theta + C$	C) $-\sin(4x)$	C) $-\infty$
D) $3\theta + 4 \cos \theta - 2 \sin \theta + C$	D) $\frac{1}{4} \sin(4x)$	D) 0
E) $3\theta + 4 \cos \theta + 2 \sin \theta + C$	E) $\sin(4x)$	E) $\frac{1}{\infty}$

Figure 3. Examples of KiSS problems for integration (left), differentiation (middle), and limits (right)

5. Findings

Although future work will portray the perspectives of various KiSS program participants and outcomes pertaining to subsequent course performance, the results reported here focus on the interaction of participants with the program. Measures of participation, accuracy, and confidence were analyzed to paint a picture of daily student activity during this implementation of the KiSS program. An analysis of charitable giving selections is not included in this paper.

5.1 Participation

Students were free to participate on any given day of the KiSS program. Therefore, looking at overall daily participation and individual amounts and patterns of participation can provide useful insight into how students responded to this implementation of the KiSS program.

5.1.1 Participation over Time

Because the number of students who received the invitation to participate in the KiSS program is unknown, it is not possible to calculate a precise participation rate. However, one measure of participation can be found by comparing the number of students who engaged in the

KiSS program with the number of students who demonstrated initial interest in participation; 59% of the students who selected a code name and texted it to the number on the flier after learning about the KiSS program went on to answer at least one of the daily problems.

Figure 4 shows how the percentage of enrolled students responding to the daily KiSS problem varied over the duration of the program. As shown in Figure 4, participation generally decreased over time with the largest drop in participation following the first 3 days of the KiSS program. Christmas Eve was the day with the fewest number of students participating. On Christmas Day (between KiSS problem #15 and #16) and New Year's Day (between KiSS problem #21 and #22), no KiSS problem was posted. However, on Christmas Day, an update revealing the current amount of points for each of the charitable causes was sent to students, and this may explain the dramatic increase in participation for KiSS #16 on the following day. In contrast, there was no drop in participation on New Year's Eve and only a small decrease in participation for KiSS #22 for the day following New Year's Day on which no problem or update was sent out.

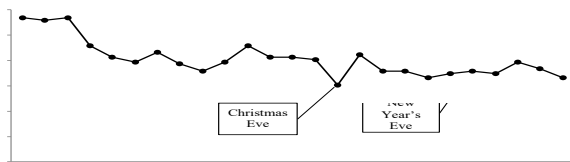


Figure 4. Percentage of students enrolled in the program who answered each KiSS problem. Hash marks represent holidays

5.1.2 Participation Amounts

Answering the question on any given day of the program was optional, so students could participate in the KiSS program as much or as little as they wished. However, only two students actively stopped participation by requesting removal of their phone numbers from the list. Figure 5 shows the number of total problems solved by students over the 25-day break. On average, students answered about 10 problems (approximately 41% of the total number of problems). As can be seen, however, the distribution of participation was roughly bimodal: students either participated very rarely (answering 5 or fewer problems) or quite often (answering more than 16 problems). Relatively few students demonstrated mid-level participation.

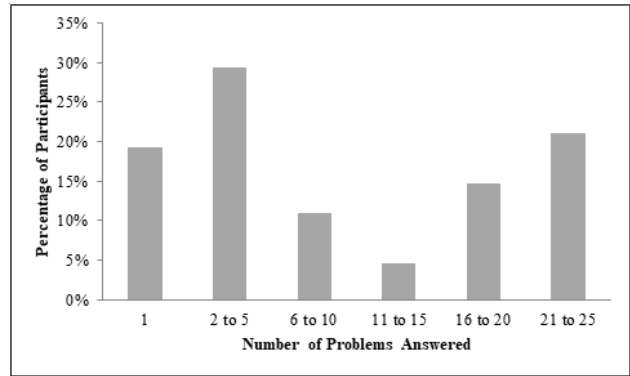


Figure 5. Number of problems answered by students.

5.1.3 Participation Amounts and Patterns

An examination of the amount and timing of participation revealed general shared patterns of activity. Figure 6 shows the date, day of the week, and problem number for the students who only answered a single KiSS problem; each row represents the participation pattern of a student, and shaded boxes indicate that the student answered the daily problem, whereas empty boxes indicate that the student did not participate. As can be seen, students who only answered one KiSS problem generally participated early on in the program, i.e., on the first day or during the first week.

Date	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	26	27	28	29	30	31	2	3	4	5
Day	M	T	W	TH	F	S	Su	M	T	W	T	F	S	Su	M	W	TH	F	S	Su	M	W	TH	F	S
KiSS Question	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Cruise																									
cminalop																									
Athenian																									
Woot																									
erikweidner																									
Katya																									
Crdavi																									
Ihathamath																									
Yaga																									
Lmai																									
Moh																									
MR97																									
azarf																									
OGMudbone																									
Madeline																									
mathsucks																									
Jdog																									
BryBry																									
Borchert																									
Captn																									
Aldo																									

Figure 6. Participation date, day of the week, and problem number for students who just participated once in the KiSS program

Figure 7 shows the participation activity for students who participated between two and five times. The students who only participated twice generally answered a problem and then, after a few days, a second problem toward the beginning of the KiSS program. Students who participated between 3 and 5 times participated in small clusters of sequential days, but also generally toward the start of the program. Some of these students, however, demonstrated what might be characterized as “bookend”

activity by answering a small number of problems at the beginning of the program and then returning toward the end of the program to answer a few more problems. Students who answered 6 to 15 of the problems had more simultaneous days of participation in each cluster, but showed a similar participation pattern to the students who answered between two and five problems with activity concentrated during the first week of the program and then falling off in the second week.

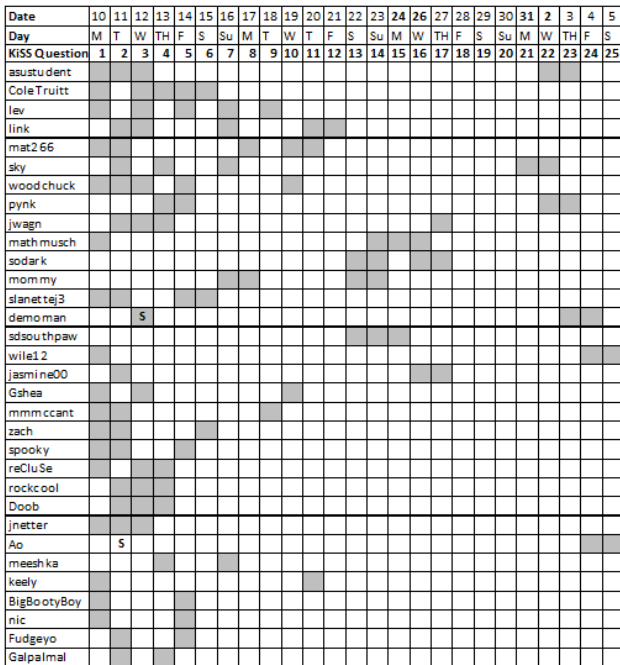


Figure 7. Participation date, day of the week, and problem number for students who participated between 2 and 5 times in the KiSS program²

Students who participated between 16 and 20 times showed large clustered days of participation with gaps in participation that spanned a few days (rather than being regularly interspersed throughout the program), as seen in Figure 8. These students appeared to take breaks (perhaps while on vacation) and then resume long stretches of participation. Finally, Figure 9 shows the activity patterns of students who answer 21 or more problems. These students generally only skipped a single day here and there over the course of the program.

Table 1 describes and characterizes the categories of participation that emerged from looking at participation patterns over the duration of the KiSS program. As participation increased in amount from answering only a single problem to answering 21 or more of the 25 problems, participation on sequential days increased and the length of gaps between these sequences of

²Some students (n=6) registered after the program had begun. An “s” in the chart indicates the day that they joined.

participation decreased.

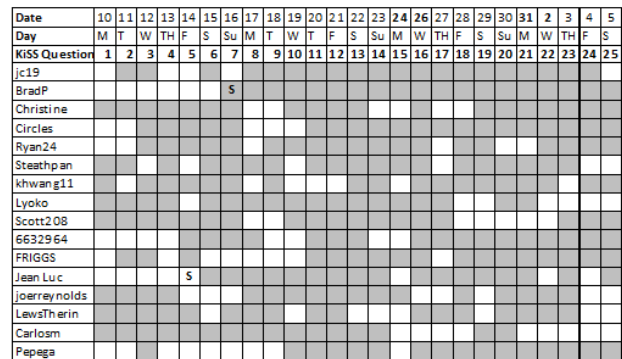


Figure 8. Participation date, day of the week, and problem number for students who participated between 16 and 20 times in the KiSS program

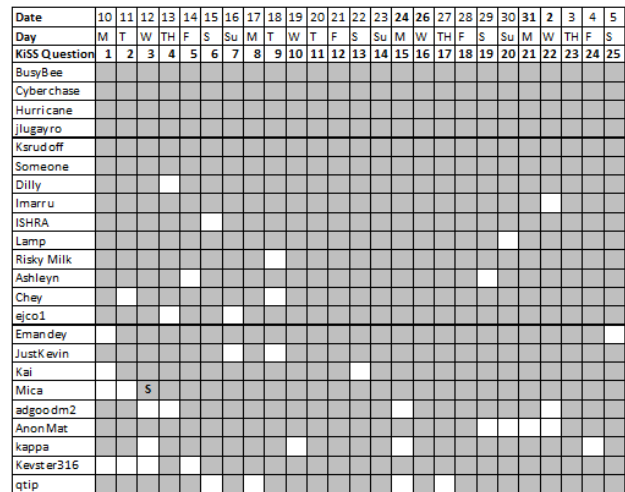


Figure 9. Participation date, day of the week, and problem number for students who participated more than 21 times in the KiSS program

Table 1. Description and characterization of KiSS program participation

Number of problems	Description of participation
1	Participated just once, generally during the first week of the program
2-5	Participated on short clusters of days, generally toward the beginning of the program
6-15	Participated on larger clusters of days, generally toward the beginning of the program
16-20	Participated on larger clusters of days, with short breaks before resuming participation
21-25	Participated regularly, with few, if any, isolated days of non-participation

5. 2 Accuracy

The main purpose of the KiSS program is to provide regular opportunities to rehearse previously learned material.

In this study, all of the problems were taken from the curriculum of the first course in the Introductory Engineering Calculus sequence that the students had just successfully completed. On average each student correctly answered 63% of the daily problems to which they responded. As Figure 10 shows, though, students who participated more in the program (e.g., answering 11 or more questions) answered a larger percentage of their problems correctly than did students who participated less.

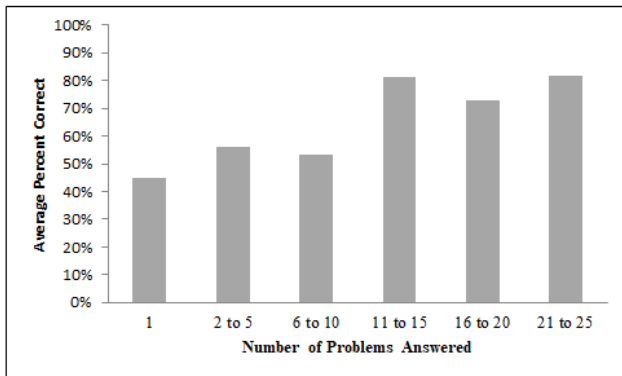


Figure 10. Average percent of problems correctly answered by number of problems answered.

Accuracy also varied across the different KiSS problems. Figure 11 shows the percentage of students who responded to each problem correctly. Across all problems, accuracy ranged from 4% (KiSS problem #16) to 57% (KiSS problem #14), indicating that students were less prepared to solve some problems in the KiSS program than others.

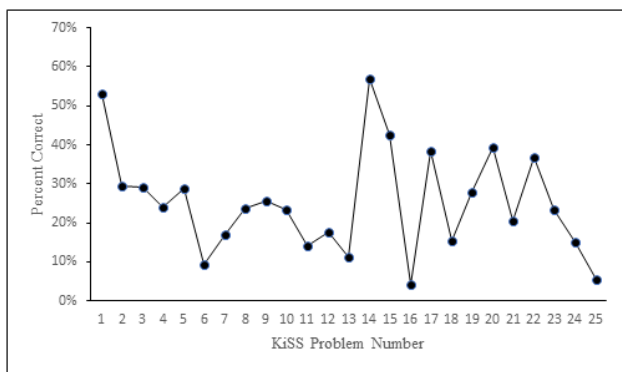


Figure 11. Percent of students who responded correctly to each KiSS problem

5.3 Confidence

Table 2 shows the distribution of confidence ratings made by students. After viewing the daily problem, students were quite confident that they would solve it; only 13% of the total ratings were either not very confident or not at all confident. And, as Figure 12, shows, students were generally accurate when they predicted they would be

able to correctly solve the daily problem; when students thought they would be able to solve the problem correctly, they were able to do so. On the other hand, there was also an indication that students underestimated their ability; almost half of the time students who were not at all confident that they would be able to correctly solve the problem were able to do so.

Table 2. Percent of ratings by confidence level

	not at all confident	not very confident	neutral	somewhat confident	very confident	Total
Percentage of ratings	5%	8%	23%	26%	38%	100%

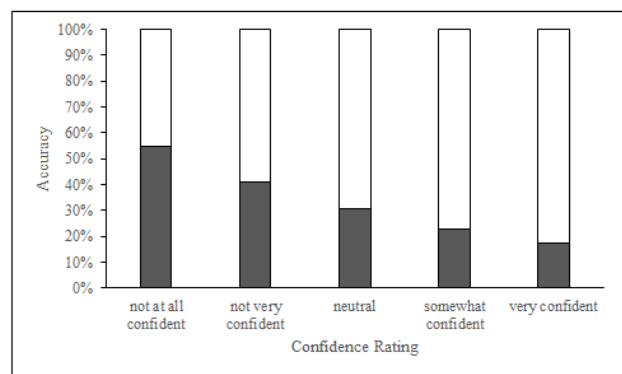


Figure 12. Percent accuracy for each confidence rating (Dark/light represents percent of inaccurate/accurate responses, respectively.)

As Figure 13 shows, confidence also varied with amount of participation. With the exception of students who only participated once, students who participated in less of the program were less confident that they would be able to correctly solve the daily problem. Students who participated only once displayed confidence ratings more similar to students who participated very regularly throughout the entire program, despite having lower accuracy on average (Figure 9).

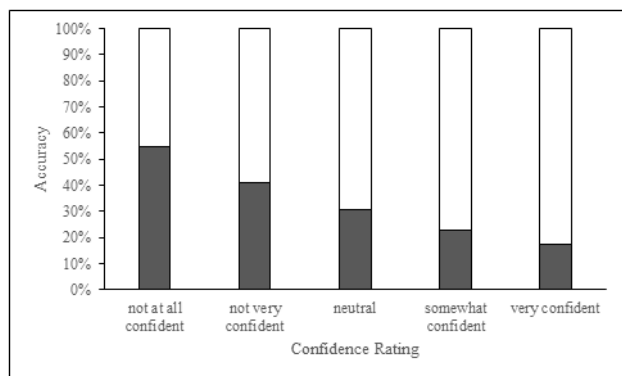


Figure 13. Percent of confidence ratings below neutral by number of problems answered

6. Discussion

This study explored participation, accuracy, and confidence in a KiSS program that was conducted during a winter break from university between two sequential introductory engineering mathematics courses. Students were texted a daily reminder containing a link to a multiple-choice problem from the first course that was considered a requisite skill or concept for the upcoming second course. After rating their confidence in being able to solve the daily problem, students indicated their response and then were provided with feedback and a solution. The KiSS program, in some ways, resembled a Massive Open Online Course (MOOC) in that it was advertised as a resource to help students maintain requisite skills during the break, and participation in the program was strictly voluntary and anonymous. Thus, students who enrolled in the KiSS program were able to participate as much, or as little, as they chose to without being penalized by an instructor. It is therefore not surprising that participation in this KiSS program was similar to that of MOOC participation with the largest amount of participation in the first few days of the program (about 50% of the those enrolled), followed by a sharp and then more gradual decline over subsequent weeks^[39]. The completion and attrition rates in the KiSS program might be accounted for to some extent by students' original intent^[40]. Some students who enrolled in the program may have done so with the intent of participating daily but then lost resolve after a short period of time, whereas other students may have enrolled with only the intent to see what the program was like but then become regular participants. Although this study did not collect data on intent, both of these potential outcomes point to the need to spark student interest immediately following program enrollment and to make the beginning of the program inviting and compelling.

One way to make the KiSS program more appealing to students might be to provide affective and cognitive support following incorrect responses. Despite the fact that the KiSS program consisted entirely of review material in multiple-choice format from a course that was just completed, many problems were answered incorrectly. Even though the program was deliberately designed to be non-threatening, getting such review problems incorrect may have a negative impact on students, especially those with lower self-efficacy^[41]. It is therefore worth considering the incorporation of messages to target persistence and growth mindset^[42], along with the inclusion of additional study and practice resources, into future KiSS program design.

In addition to lower accuracy, students who participated less in the program showed less confidence in their ability

to solve the daily problem. Therefore, another way to encourage persistence might be to incorporate a range of problem difficulty levels in the KiSS program. Ideally, the selection and difficulty of each daily problem would be tailored to individual student ability with the aim of boosting the self-confidence of students who are unable to recall a particular skill or concept, while at the same time allowing other students to challenge themselves and not become bored. In addition to potentially improving participation, adaptive problem selection based on dynamically generated problem difficulties has been shown to have a positive effect on student learning performance^[43].

Taken together, analyses of participation, accuracy, and confidence in this implementation of the KiSS program provide valuable insight into ways that the program can be improved and optimized for future implementation. The ultimate goal is to bridge the gap between sequential courses and stem the loss of learning by providing regular and convenient retrieval practice opportunities over school breaks. Future work will include outcome measures, such as perception of preparedness and course retention, and experimental studies to determine whether the KiSS program is living up to its name by keeping students in shape over breaks from formal instruction.

7. Conclusion

In the same way that a daily desk calendar can prompt people to work on a solution to a puzzle (e.g., a tangram) when they rip off the previous page and see the new puzzle for the first time, the KiSS program puts a daily math problem in front of students to entice them to solve it. Unlike paper desk calendars, though, the KiSS program delivers a nudge campaign through text messages so that it is accessible and visible to a broad student audience. Implementing the KiSS program to university students enrolled in a sequence of introductory calculus courses over winter break revealed that this strategy has promise for getting students to test themselves regularly. In doing so, they rehearsed previously learned material that is requisite for future learning and were made aware of gaps in their knowledge. The KiSS program therefore represents a viable resource that supports retrieval practice over breaks from formal instruction.

An additional benefit of the KiSS program is that the underlying concept can be implemented in a wide range of instructional contexts in which lengthy time gaps contribute to student inactivity. In particular, the KiSS program is easily adaptable for use in other subject areas and with other student populations as a resource to reach students when they are outside of the classroom for an extended period of time. Assembling a library of various

nudges (questions, problems, etc.) for this purpose could be a community endeavor in which instructors with shared experiences contribute material that they deem worthy of student rehearsal. In this way, the KiSS program not only connects individual instructors with students but can also serve as a collaborative frame for instructors to engage in action research.

New learning is constructed and built upon prior knowledge. Therefore, keeping requisite knowledge fresh and accessible is vital for student success. This paper describes a pioneering effort to use a novel combination of various technologies to reach students when they are away from the classroom and encourage them to rehearse essential skills and concepts. By heeding lessons learned from experience and also thinking ahead about design and implementation improvements and expansion, the hope is that the KiSS program concept will help many students stay in shape as they reach each new stage in their educational journey.

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