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Engaging Students in Retrieval Practice Over Academic Breaks

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Abstract

Students lose valuable ground over breaks from school, and this issue is even more problematic given the detrimental effects of the COVID-19 pandemic on student progress and learning. The Keep in School Shape (KiSS) Program represents a way of engaging students in reviewing previously learned material that they need to maintain over academic breaks. The KiSS program repurposes existing online survey software to nudge students to engage in daily retrieval practice opportunities via text message or email, together with supporting resources, including hints, solutions, and empowering feedback messages. This paper describes the design of the KiSS Program and presents select results for a run of the KiSS Program during the 2022 winter break involving introductory level Calculus students at a large university. Findings indicate that such a program can get students to voluntarily rehearse previously learned material over breaks from school, and that students use the program in ways that are consistent with a growth mindset.

Keywords: retrieval practice, nudges, growth mindset, learning loss, mathematics education

1. Introduction

During the school year, instructors build on what students have previously learned. But during lengthy breaks from school learning gains can erode when students do not regularly engage with the material that they have recently learned. The problem is how to provide convenient, cost-effective, and engaging review opportunities to students when school is not in session so that they maintain what they have learned and return to the classroom prepared and ready to continue their educational journey. This paper describes the Keep in School Shape (KiSS) Program that was developed to address this challenge by nudging students to engage in retrieval practice opportunities over academic breaks.

1.1 Learning loss

Students must not only remember what they learn throughout a school year, but they must also retain what they have learned over periods of time when school is not in session. This is not easily done. The stagnation (von Hippel et al., 2018), or even loss (Cooper et al., 1996), of learning over lengthy breaks from school is well documented in Kindergarten through High School education for several school subjects, and even extends to higher education (van de Sande & Reiser, 2018). This loss of learning has been attributed to a lack of educational enriching activities over academic breaks (Quinn & Polikoff, 2017), but breaks from formal instruction also create event boundaries and thereby set the stage for intentional forgetting to occur (Ramirez et al., 2017). Extending educational activities beyond the school year or academic term is one way of addressing these issues that especially harm disadvantaged students (Downey et al., 2004; Kim & Quinn, 2013; Lenhoff et al., 2020). The KiSS Program answers this call by providing free review opportunities to students over academic breaks so that they can maintain what they have recently learned and will be using in their future studies.

1.2 Retrieval Practice

Transience, the process of forgetting that occurs with the passage of time, can be offset by consciously reviewing learned material (Schacter, 2001). The benefits of such rehearsal, known as retrieval practice, have been repeatedly documented in both laboratory settings and classrooms (Butler et al., 2014; McDaniel et al., 2007). Retrieval practice leads to flexible understandings, improved higher-order thinking skills, and knowledge transfer by revealing to students what they have and have not mastered (Agarwal et al., 2013). One tenet 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 (Roediger & Butler, 2011). This phenomenon has been dubbed the “testing effect” (Roediger & Karpicke, 2006). In essence, testing provides students with retrieval practice opportunities shown to be beneficial for retaining information and knowledge transfer (Butler, 2010; Johnson & Mayer, 2009; Rohrer et al., 2010).

Retrieval practice is most effective when spaced out rather than massed in large episodes

(Carpenter et al., 2012; Cull, 2000; Pashler et al., 2007, Rohrer & Pashler, 2007). Students, however, think that the reverse is true and favor "cramming" over regular review (Kornell, 2009). Therefore, finding appealing ways of encouraging students to engage in spaced practice is challenging, even inside the classroom (Kapler et al. 2015). The KiSS Program represents an innovative and cost-effective way of nudging students to engage in retrieval practice opportunities over academic breaks.

1.2 Nudges

A nudge is some small feature of the environment that attracts our attention and alters behavior (Thaler & Sunstein, 2008). The power of nudges has been well established in contexts that range from personal lifestyle issues (Woolford et al., 2010) to major life decisions (Castleman & Meyer, 2016). They are a nonthreatening and effective way of sustaining attention and focus by delivering regular advice, support, and reminders (Karlan et al., 2010; Obermayer et al., 2004), especially to at-risk populations (Castleman & Meyer, 2016; Castleman & Page, 2014; 2015). Nudges delivered via text messages have shown promise for increasing student engagement (Kraft & Dougherty, 2013) and preventing summer learning loss of literary proficiency (Kraft & Monti-Nussbaum, 2017). The KiSS Program harnesses the power of nudges for engaging students in maintaining STEM proficiency over academic breaks.

1.3 The Keep in School Shape Program

Each day over academic breaks, the Keep in School Shape (KiSS) Program sends students a reminder and a link to a review activity. These are delivered via short message service (text) or email, depending on a student's preference. The reminders are fun invitations to participate, often containing rhymes and puns. The accompanying link takes students directly to the start of the review activity which is housed in Qualtrics, an online survey platform. The design of the KiSS Program, together with the use of online survey software, gives it the appearance and feel of an app without incurring substantial costs on the part of the developer and without requiring students to install a piece of software on their devices. When students enroll in the KiSS Program, they select from one of three daily times (spanning morning, afternoon, and evening) to receive their review activity which remains open for 24 hours. Students may participate on any day they choose and may opt out at any time during an academic break session.

There are two levels of difficulty (Level 1 and Level 2) within each review activity, where Level 2 problems are mathematically related to Level 1 problems, but slightly more challenging. (For example, a Level 1 problem might require one operation to reach the solution, whereas the associate Level 2 problem would require two operations.) Each day of the KiSS Program, students can choose to start at Level 1 or bypass Level 1 and advance directly to Level 2. Once students select their daily starting level, they are shown a problem at that level and asked to rate how confident they feel for being able to solve it. These confidence ratings represent judgments of learning (Rhodes, 2016) and are a way for students to reflect on how well they remember certain skills before attempting them. A 5-point smiley scale with informal labels ranging from "not at all!" to "super duper!" adds personality and

global interpretability to this reflection (Sedley et al., 2020). This lighthearted approach to rating confidence also reflects empathic design efforts (Kouprie and Visser, 2009) since it is intended to minimize the potential math anxiety that some students experience from being presented with a mathematics problem (Pizzie and Kraemer, 2017). Figure 1 shows an example of what a student receiving the KiSS Program via text messaging would see, from the initial invitation and link (left) to the choice of starting level (middle) and the confidence rating (right). The confidence ratings also are used in the KiSS Program to help students adjust their starting level. If a student opts to start at Level 2 but then indicates that they are not confident in their ability to solve the Level 2 daily problem, the KiSS Program does not automatically advance them to the Level 2 review problem but instead offers them the choice of continuing on in Level 2 or switching to Level 1 before later attempting Level 2.

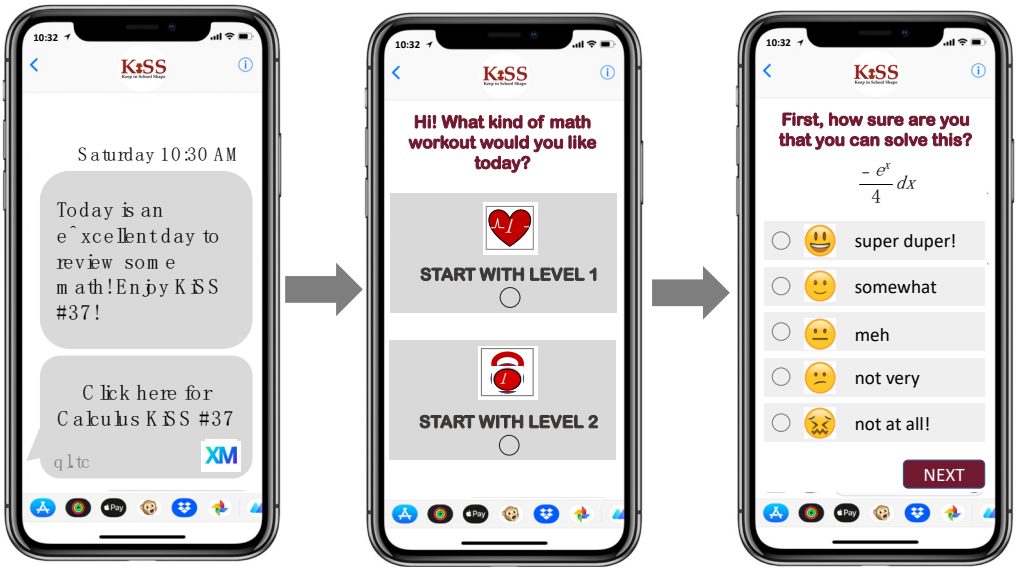

Figure 1. Example of the daily invitation and link (left), choice of starting level (middle), and confidence rating (right)

Once students have decided on a starting level and rated their confidence for the initial problem at that level, they solve the problem by choosing from five possible answers, where the distractors represent common errors that students make when solving the problem. Multiple choice questions, despite their limitations (Nicol, 2007), are well suited for this purpose because they do not require students to enter in complicated mathematical expressions in order to participate. As shown in Figure 2, after they make their answer selection, different options or paths become available to them, sometimes depending on whether their answer is correct or incorrect. All of the paths that are available to student in each daily review activity are controlled by skip logic built into the Qualtrics online survey that houses it. For instance, if a student chooses to start at Level 1 and gets the initial problem in the daily review activity correct, they have the option to view the solution, move directly to Level 2, or exit for the day. If a student chooses to start at Level 1 and gets the initial problem incorrect, they have the option to view a hint and retry the problem, view the solution, or exit.

The solutions are handwritten step-by-step solutions that also show students where the skill fits into a problem they will encounter in their future studies.

If a student chooses to exit after only making an answer selection (correct or incorrect) for the initial Level 1 problem and not engaging further in the daily activity, they are asked whether they are sure that they want to exit and given the opportunity to make the choice again. This is referred to as a "soft exit" since choosing "exit" the first time does not automatically conclude the daily review activity. By requiring confirmation and allowing an alternative decision, these soft exits are similar to confirmation dialogs that appear in User Interfaces (UI). However, confirmation dialogs in UI are primarily used for the purpose of preventing user error (Nielsen, 2018); soft exits in the KiSS Program are used to promote a growth mindset by prompting students to rethink their decision of quitting after a low amount of engagement.

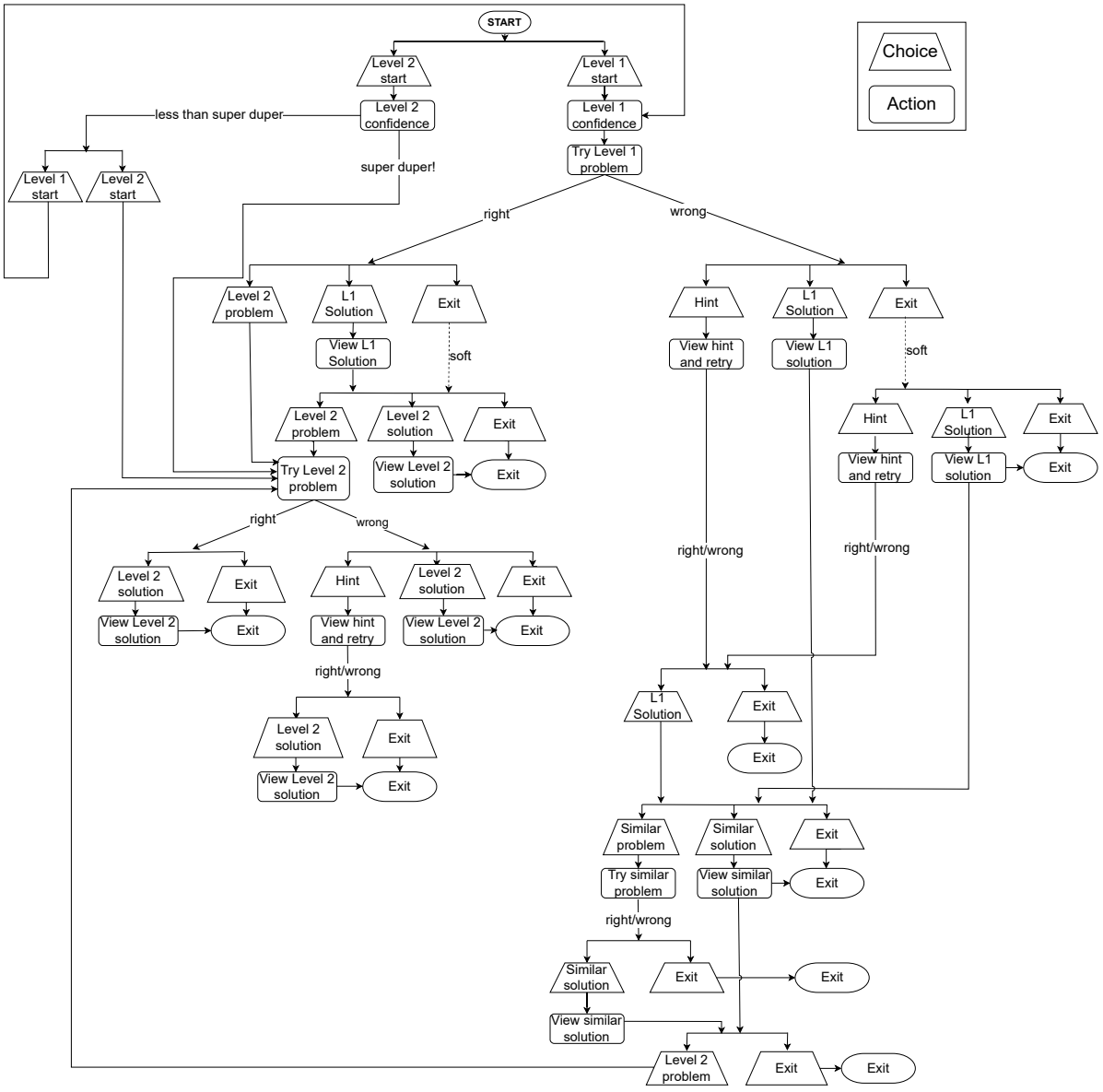

Figure 2. Flowchart depicting paths through the daily review activity

In addition to prompting students to persist and paths that allow students to learn from their mistakes and challenge themselves, the KiSS Program explicitly supports a growth mindset, or the belief that abilities can be developed with effort (Dweck, 2016), through feedback. Messages following incorrect responses encourage students to persevere, and messages following correct responses encourage students to push themselves by taking on a more challenging problem. Many of these messages, as shown in Figure 3, are inspirational quotes from renowned Educational Psychologist, Carol Dweck.

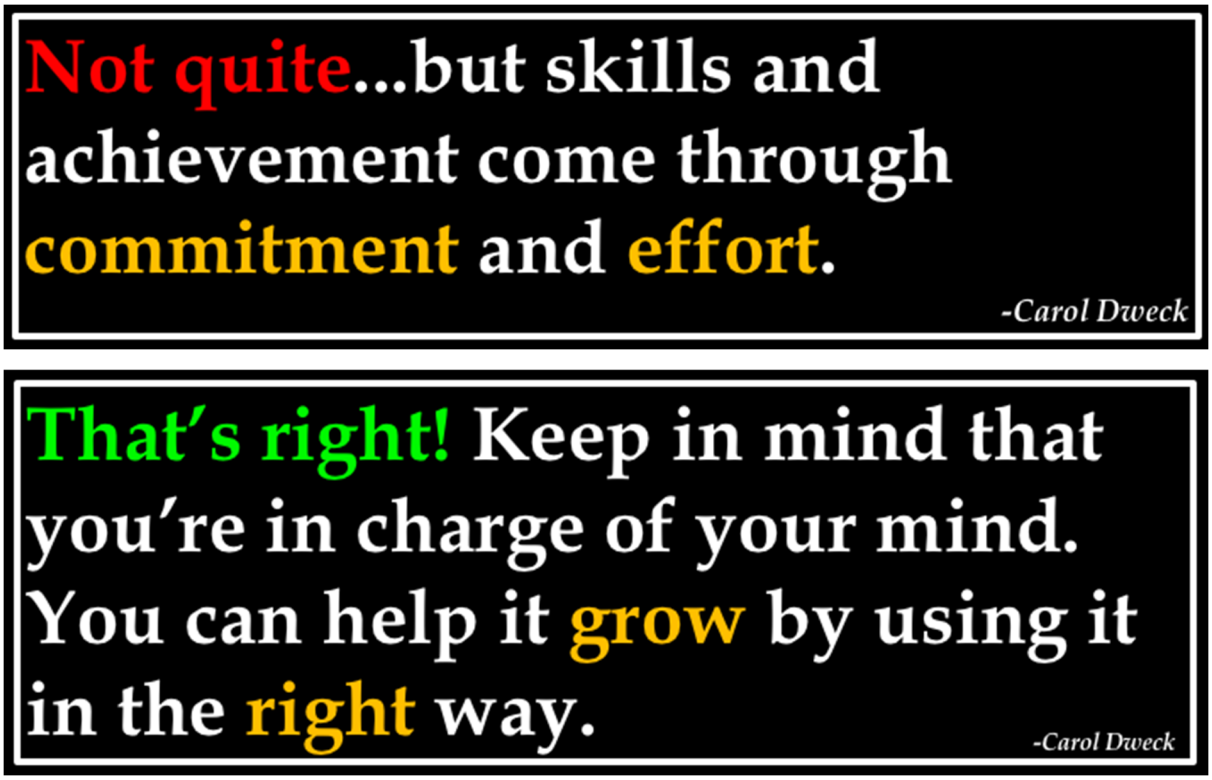

Figure 3. Example of explicit growth mindset messages

2. Method

This work uses an observational methodology to explore how students engage with the KiSS Program. Housing the KiSS Program in Qualtrics facilitates unobtrusive data collection on participation, confidence, accuracy, and the paths that students take as they navigate each daily review activity. Qualtrics provides a spreadsheet for each daily review activity that identifies the participant, the timing of their participation, and the choices they made within the daily activity. These data files were then compiled into a single file that contained the data for every day of the KiSS Program.

This paper reports on select results from a run of the KiSS Program over the 2022 winter break at a large southwestern university. Students who had enrolled to take the second semester of a Calculus for Engineers class (Calculus 2) in the Spring 2023 semester were invited via email to participate in the KiSS Program and review key skills and concepts from

the first semester Calculus course (Calculus 1). The KiSS Program is provided as a free resource that is available to *all students* enrolled to take Calculus 2 after break. We do not collect demographic information on participants. The recruitment flier can be seen in Figure 4. With the exception of Christmas Day and New Year's Day, the KiSS Program sent out review activities on each day of the break, resulting in 26 total review activities.

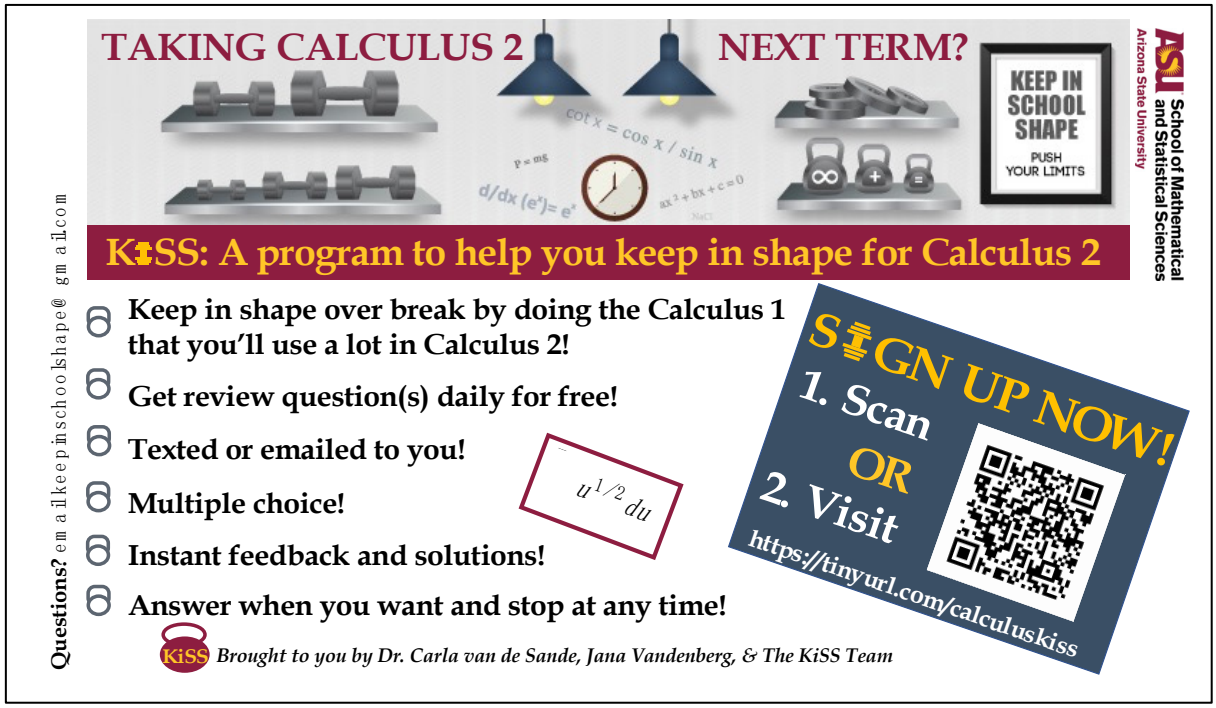

Figure 4. Recruitment flier

3. Results

3.1 Participation

We cannot establish a participation rate relative to the population of students who were sent invitations for the KiSS Program since we do not know how many students received and opened their invitation. However, we know that 459 students signed up to participate in the program, which by a conservative estimate represents 21% of the students who eventually enrolled in the Calculus 2 course. 337 of these 459 students (73%) opened at least one daily KiSS review activity.

Figure 5 shows the number of students who opened up the daily review activity by problem number. When students signed up for the KiSS Program, they could elect to start immediately on the first day of winter break (Problem Number 1) or take a 4-day "burn out" break and start on the fifth day (Problem Number 5). As Figure 5 shows, many students chose to take a few days off following the end of the semester before they began receiving the daily review. Figure 4 also shows that, in general, participation numbers remained fairly steady over the

course of the break, even close to the major holidays (Christmas fell between Problem Numbers 13 and 14 and New Year's Day fell between Problem Numbers 19 and 20).

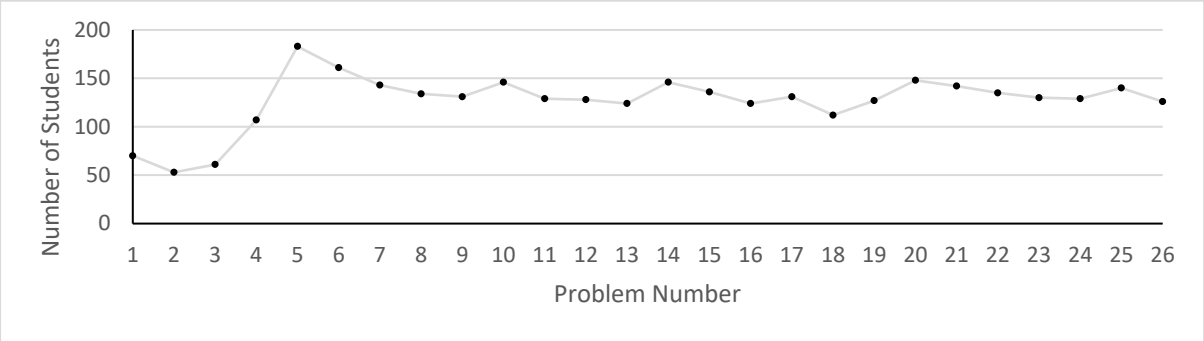

Figure 5. Number of students who opened up the daily review activity by problem number

Figure 6 shows the number of students who participated by the percentage of the days that they were enrolled in the KiSS Program. Many students tried out the program on one or two days, mostly towards the beginning of the academic break, but then did not participate further. On the other extreme, there were many students who participated on more than 91% of the days that they were enrolled in the program. The average percentage of problems started was 48.6%.

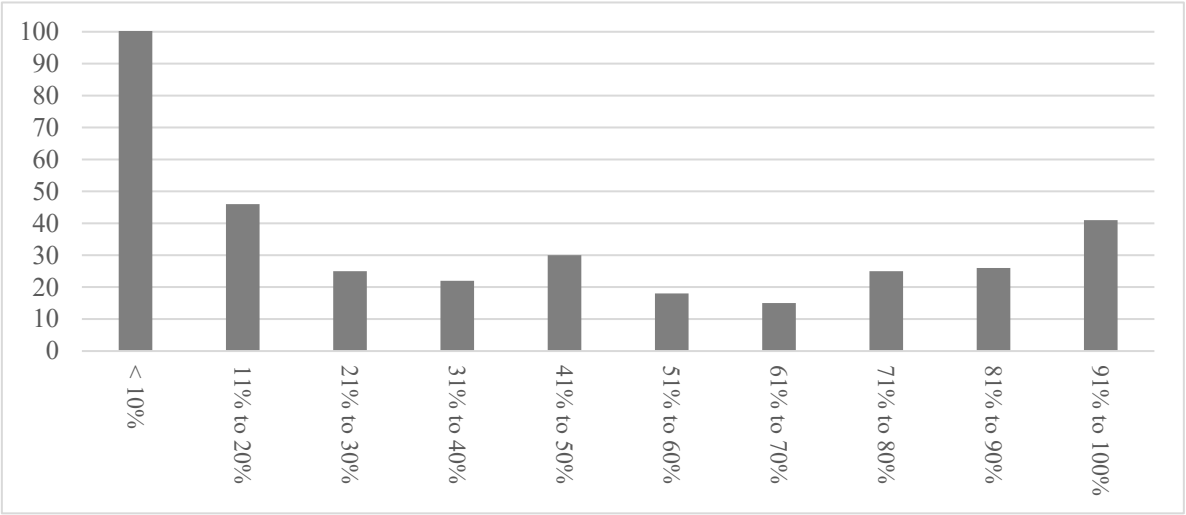

Figure 6. Number of students who participated given percentage of days enrolled

3.2 Soft Exits

When students tried to exit directly after responding (either correctly or incorrectly) to the daily Level 1 problem, they are prompted to reconsider their decision. This design decision

was made following observations from previous implementations of the KiSS Program that some number of students did not take full advantage of the resources available in each daily review activity to either challenge themselves further or to treat their error as an opportunity for learning (van de Sande & Vandenberg, 2021b). For this implementation of the KiSS Program, very few students tried to immediately exit after the first attempt, but instead completed on average 2.02 of the three problems available (initial Level 1 problem, similar Level 1 problem, and Level 2 problem) in each daily review activity. Of the students who opted to exit, fewer did so after getting the initial problem incorrect than did after getting the problem correct. A soft exit is considered effective if a student decides to engage further with the daily review activity. Figure 7 shows the effectiveness of the soft exits depending on whether the prompt followed a correct or incorrect response to the initial daily Level 1 problem. Soft exits tended to be more effective after incorrect responses when students were asked to reconsider their decision to exit and instead view a hint or the solution to the problem. They were less effective after correct responses when students were asked whether they wanted to progress to Level 2 or view a solution to a Level 2 problem instead of exiting.

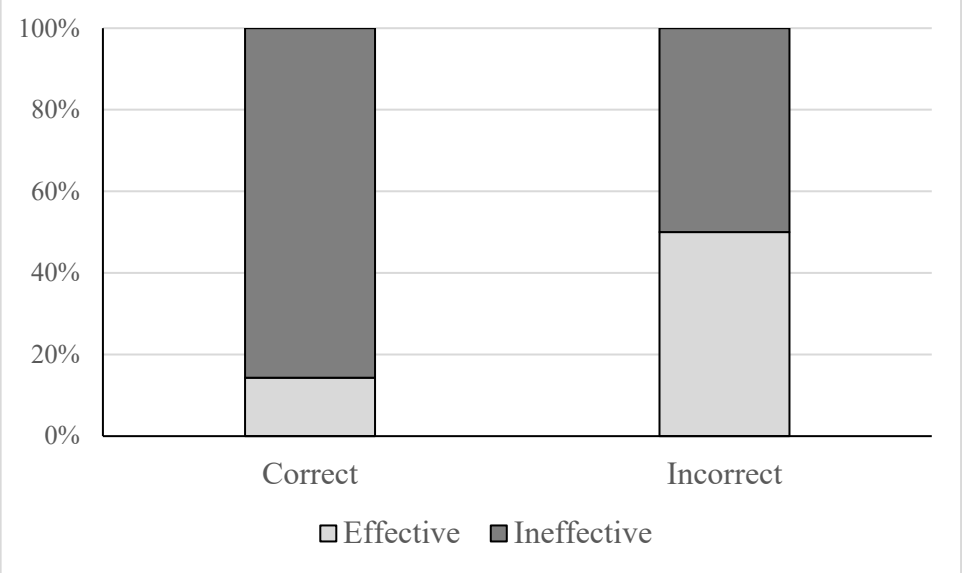

Figure 7. Effectiveness of soft exits following correct and incorrect responses

3.3 Hints and Solutions

When students answered a Level 1 problem incorrectly on their first attempt, they had the option of viewing a hint and attempting the problem again, viewing the solution to the problem, or exiting for the day. The hint and solution options both allowed a student to eventually try additional problems (a problem similar to the initial Level 1 problem and a Level 2 problem) in the daily activity. Figure 8 shows the percentage of responses for each choice for the Level 1 problems by Level 1 confidence rating. Across all confidence levels, getting a hint was the most popular choice (76% of the total instances), followed by viewing the solution (21% of the instances). The choice to exit or not make a choice only occurred in very few instances (3% of the instances).

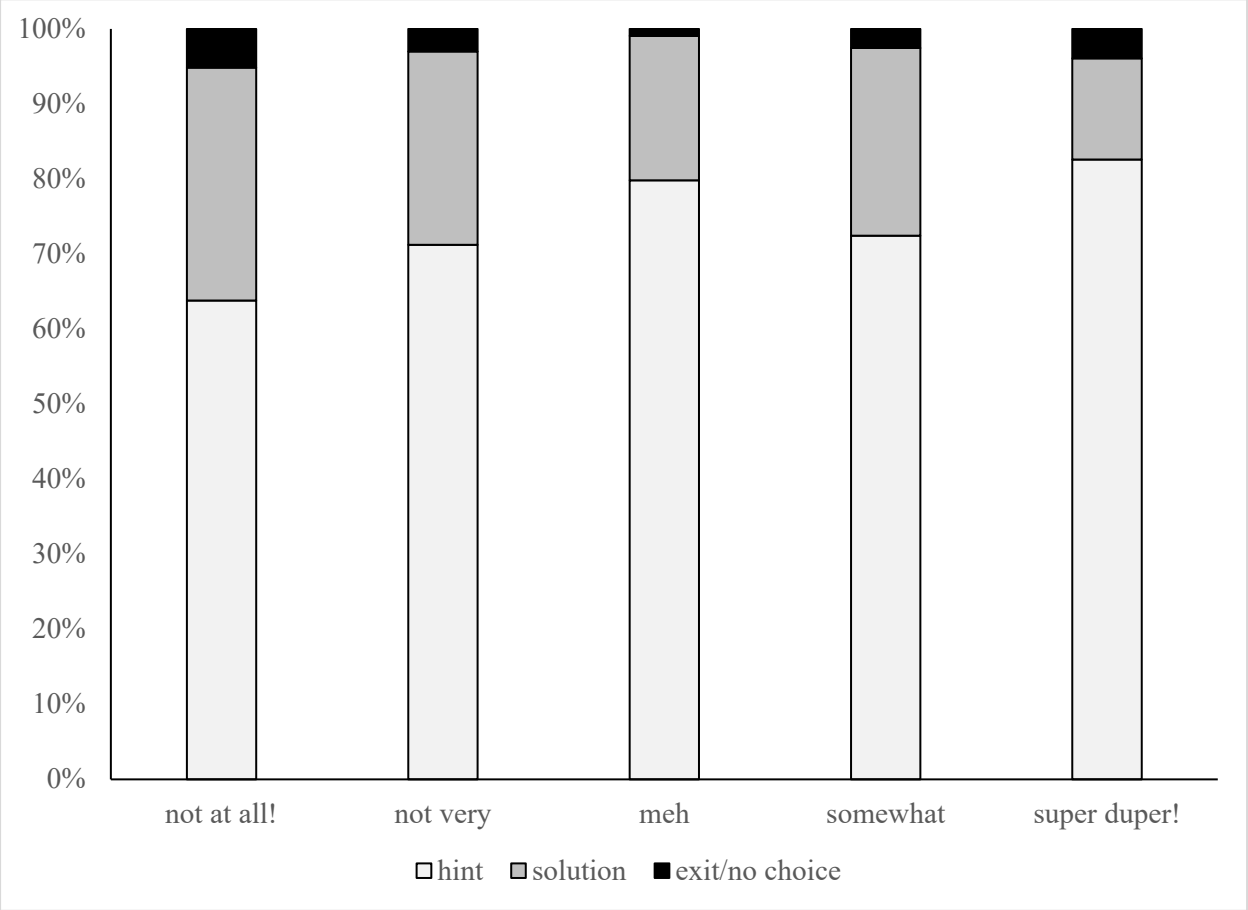

Figure 8. Choice following incorrect response to Level 1 problem by Level 1 problem confidence

3.4 Challenges

When students answer a Level 1 problem correctly on their first attempt, they have the option of progressing directly to Level 2, viewing the solution to the problem before deciding to whether to attempt a Level 2 problem, or exiting for the day. As shown in Figure 9, confidence in ability to solve the Level 1 problem played a role in whether students proceeded directly to Level 2. Increasing confidence in the ability to solve the Level 1 problem correctly prior to having correctly solved it was positively correlated with the choice to immediately attempt a Level 2 problem.

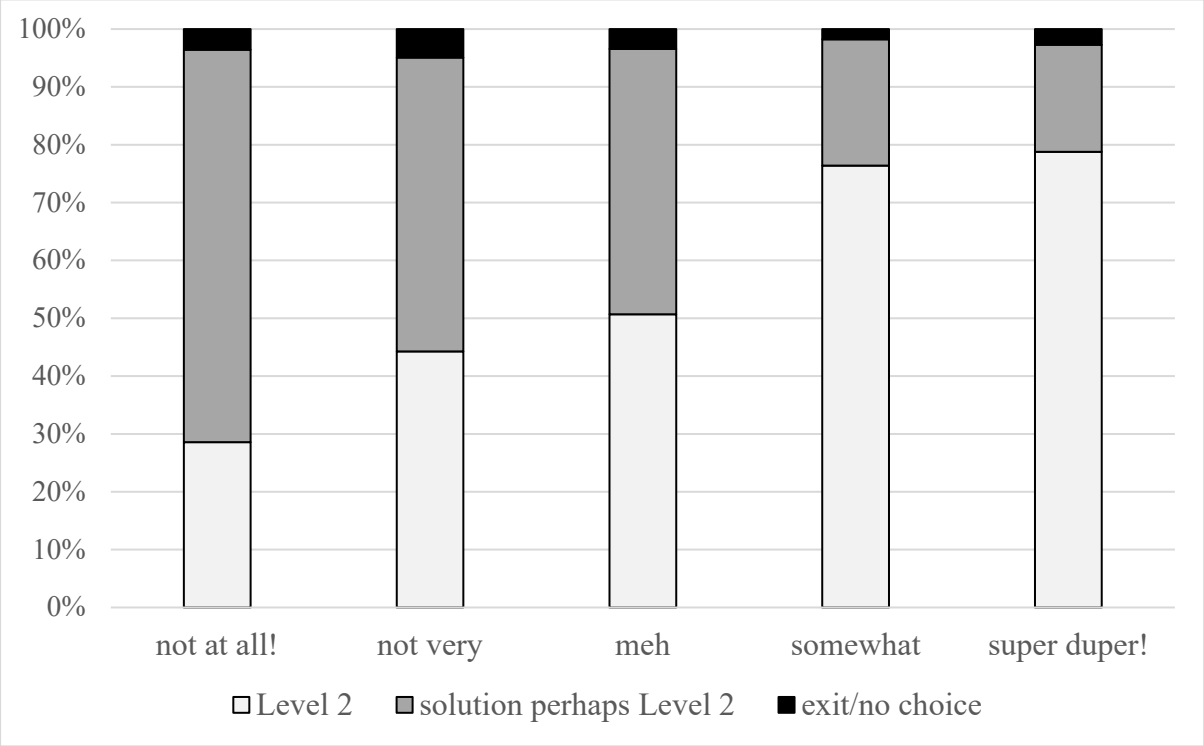

Figure 9. Choice following correct response to Level 1 problem by Level 1 problem confidence

Viewing the solution, however, was not indicative of exiting. It was instead treated as a gateway further engagement. After viewing the solution to the Level 1 problem, 88.7% of the time students progressed to Level 2. Table 1 shows the percentage of instances that progressed to Level 2 according to Level 1 problem confidence rating. Although it was somewhat less common for students with the lowest level of confidence to take on a challenge after viewing the solution, progressing to Level 2 was a very popular decision after getting the Level 1 problem correct on the first attempt.

Table 1. Percentage of instances for progression to Level 2 by Level 1 confidence rating

Level 1 confidence	Progress to Level 2
not at all!	68.4%
not very	93.5%
meh	94.0%
somewhat	91.8%
super duper!	86.7%

4. Discussion

The KiSS Program helps students maintain their previous learning by nudging them to engage in retrieval practice over academic breaks. It makes this practice convenient since students can opt to receive the program via text message or email. With such a program, students are willing to voluntarily review math skills when school is not in session. Also, once students start engaging with such a program by opening up the daily activity, they almost always complete the problems they start, and many continue on to complete more than one problem that is part of the daily review activity. And, as students are working through the daily activity, they make use of the hints and solutions that the program offers. The solutions were especially used by students who lacked confidence in their ability but still got a problem correct as a gateway to attempting a more challenging problem.

These findings are promising. Finding a way to engage students in reviewing previously learned material over academic breaks has the potential to decrease the loss of learning that occurs when skills are not rehearsed when school is not in session. And, the recent COVID-19 pandemic and school closures have further amplified the need for students to be able to steadily progress through school without losing any additional ground (Kuhfeld et al., 2022). In the wake of the pandemic we are facing significant decreases in standardized test scores, together with an increase in academic disparities between social classes (Goudeau et al, 2021). There is a pressing need, therefore, for interventions and strategies to address these critical and devastating problems. The KiSS Program, which continues to grow and evolve in the ways in which it supports review, is one such innovation (van de Sande & Vandenberg, 2021a). Although originally developed for Calculus students in higher education, it can be easily modified to meet the needs of students in other grade levels and subject areas. The KiSS Program represents a cost-effective and student-friendly way of getting students to regularly rehearse the skills that they have learned and need to maintain so that they do not slip backwards over breaks from school but instead continue to make forward progress on their educational trajectories.

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