The Canadian Journal for the Scholarship of Teaching and Learning

Volume 12 | Issue 1 Article 5

Fall 09-20-2021

A Metacognitive Instructional Guide to Support Effective Studying Strategies

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https://doi.org/10.5206/cjsotl-rcacea.2021.1.8318

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Abstract
Metacognition—the processes whereby learners assess and monitor their progress in learning (metacognitive monitoring, MM) and use these judgements of learning to make choices about what to study in the future (metacognitive control, MC)—has been shown to be beneficial to learning. However, effective learning also relies on metacognitive knowledge (MK)—that is, students' knowledge about effective study strategies and how to employ them. Few students receive explicit in-class instruction on these topics. Here, we explore if an online instructional guide, which includes information about evidence-based study strategies, example questions for self-testing, and a study calendar to help regulate timing of studying can effectively teach MK to improve performance.

While it is unclear if the online instructional guide was related to increases in MK, MM, and MC, we did observe benefits to student performance, particularly in highly anxious students on high-stake assessments such as the final examination. Future research should seek to understand how students were engaging with the guide and how the nature of the engagement impacted their study strategies.

Il a été montré que la métacognition – les processus par lesquels les apprenants et les apprenantes évaluent et suivent leurs progrès en apprentissage (surveillance métacognitive) et utilisent ces jugements d'apprentissage pour faire des choix concernant ce qu'ils veulent étudier à l'avenir (contrôle métacognitif) – est bénéfique à l'apprentissage. Toutefois, l'apprentissage efficace s'appuie également sur la connaissance métacognitive, c'est-à-dire sur le fait que les étudiants et les étudiantes connaissent les stratégies d'études efficaces et savent les employer. Peu d'étudiants et d'étudiantes reçoivent des directives explicites en classe sur ces sujets. Dans cet article, nous tentons de voir si un guide d'instruction en ligne, qui comprend des informations sur des stratégies d'études fondées sur des données probantes, des questions pour effectuer des auto-évaluations, ainsi qu'un calendrier d'apprentissage pour régulariser l'emploi du temps des études, peut effectivement enseigner la connaissance métacognitive afin d'améliorer les résultats.

Bien qu'il ne soit pas clair si le guide d'instruction en ligne était relié aux augmentations en matière de connaissance métacognitive, de surveillance métacognitive et de contrôle métacognitif, nous avons toutefois observé des avantages dans les résultats des étudiants et des étudiantes, en particulier parmi ceux et celles qui souffrent fortement d'anxiété quand ils et elles doivent faire des travaux importants tels que les examens finaux. Des recherches futures devraient chercher à comprendre comment les étudiants et les étudiantes avaient utilisé le guide et comment la nature de leur engagement avait affecté leurs stratégies d'études.

Keywords
metacognition, study strategies, online, assessment anxiety; métacognition, stratégies d'études, en ligne, anxiété face aux évaluations

This research paper/Rapport de recherche is available in The Canadian Journal for the Scholarship of Teaching and Learning: https://doi.org/10.5206/cjsotl-rcacea.2021.1.8318

Metacognition, applied to learning, describes a person's ability to identify concepts they do not understand and implement appropriate strategies to learn these concepts (Schraw et al., 2006). Much of the literature about learning is examined within a metacognitive framework of monitoring and control (de Bruin et al., 2017; Kelemen et al., 2007; Miller & Geraci, 2011; Schraw et al., 2006), whereby learners assess and monitor their progress while learning (metacognitive monitoring, MM) and use these judgements of learning to make choices about what and how to study in the future (metacognitive control, MC). Indeed, MM has been shown to be beneficial to learning (Hartwig et al., 2012) as it allows students to assess their comprehension and identify concepts for additional study (Thiede et al., 2003). However most students, especially low performing students, have poor MM skills (Ehrlinger et al., 2008; Lewine & Sommers, 2016; Saenz et al., 2017). Consequently, interventions to improve MM and subsequently MC have been the focus of much study in recent years (for examples see de Bruin et al., 2017; Dunlosky & Rawson, 2015; Mynlieff et al., 2014; Zepeda et al., 2015); however, these interventions vary in effectiveness and tend to demand a high level of resources, therefore presenting challenges to implementation—especially in post-secondary education.

The Metacognitive Framework and the Importance of Metacognitive Knowledge

Both MM, MC and the interactions between them are important within the literature on learning. MM is the capacity to identify and evaluate discrepancies between current comprehension and desired comprehension. MC is the ability to regulate behaviours affecting cognition including the allocation of study time and selection of learning strategies. A wealth of research supports this dualistic framework, whereby monitoring is used to guide the control process through the selection of ill-learned material for additional study (Hartwig et al., 2012; Karpicke, 2009; Thiede et al., 2003). However, many models of metacognition make the distinction between the processes involved in MM and MC and metacognitive knowledge (MK) (Pintrich, 2002).

MK is described as the knowledge of strategies that can be used in learning, an understanding of their effectiveness under various conditions, and an awareness of how one's self relates to each strategy (Flavell, 1976; Pintrich, 2002). There is a substantial volume of literature describing which learning strategies are most effective (for examples see Dunlosky & Rawson, 2015; Karpicke, 2009; Rawson et al., 2013). However, outside of the strict experimental control of laboratory studies, students are left to rely on their MK to select their own study strategies, and these chosen strategies may vary in effectiveness. Indeed, multiple studies have shown that when given a choice on how to study, students often do not select the strategies supported by the literature (Birnbaum et al., 2013; Karpicke, 2009). One study found that students avoided active learning strategies because they believed that those strategies were more difficult to implement (Dye & Stanton, 2017). Another study looking to the relative effectiveness of two study strategies found that student perceptions of which study strategy was more effective did not align with the strategy that actually benefited their performance (Birnbaum et al., 2013). These findings indicate that students may have poor MK skills and outline the importance of teaching students about learning strategies with the assumption that neither MM nor MC can have any impact on performance if the student is unaware of effective methods of studying.

On the Feasibility of Intervention

Many studies have investigated the effectiveness of interventions targeted at improving MM and MC both in laboratory (see Kelemen et al., 2007; Thiede et al., 2003) and classroom contexts (see de Bruin et al., 2017; Miller & Geraci, 2011; Nietfeld et al., 2005) to highly variable results. Collectively, these studies suggest that while practicing MM and MC on their own is insufficient (Nietfeld et al., 2005), practicing these skills combined with feedback on their effectiveness (Miller & Geraci, 2011), particularly when instruction is explicit (Zohar & David, 2008), can have a significant positive impact on overall metacognition and exam performance in students.

Together, these empirical results provide an argument for the importance of explicitly teaching the study principles associated with MK. Indeed, much of recent literature has recommended that instructors focus on explicit instruction when seeking to improve overall metacognition (Askell-Williams et al., 2012; Dye & Stanton, 2017; Kelemen et al., 2007; Miller & Geraci, 2011; Stanton et al., 2015). However, explicit teaching places much higher demands on teaching resources as it requires more time (whether in class or in addition to class) and requires the instructor to be knowledgeable about metacognition in the context of learning. This presents challenges to post-secondary education where instructors tend to be highly specialized, class sizes are large, and class time is limited. Digital learning has the potential to address these challenges and is often used to mediate educational constraints in post-secondary education. Studies have shown that an online guide which demands few resources can effectively support learning in some instances (Archer & Olson, 2018; de Bruin et al., 2017). Here we develop a tool to address the challenges of large class learning in which metacognitive strategies cannot be explicitly taught, however it remains unclear if a digital intervention can replace in-person metacognitive training.

The Present Study

Based on the importance of MK, and with the goal of improving the effectiveness of student learning behaviours at a low-resource cost, we designed an instructional guide consisting of a document about effective studying and a study schedule to be distributed using the online portion of a first-year biology course. If the guide is sufficient to effectively teach metacognitive knowledge (our working hypothesis), then we predicted that use of the guide would be positively related to measures of (a) MK, (b) MC, (c) MM (d) absolute and (e) relative measures of performance.

Method

Site and Participants

This research was conducted within the Biology department at a mid-sized comprehensive university in Ontario, Canada. Undergraduate students enrolled in a first-year introductory biology course in the fall semester of 2017 (F17) were invited to participate.

Survey data were collected from 105 individuals out of 450 enrolled in the course, for a response rate of 23%. However, 44 individuals were removed from analysis due to incomplete data or because they did not fit the inclusion criterion, resulting in 61 participants in total (n=61).

In addition to obtaining ethics clearance (REB#17-08-030), we obtained permission from these students to use their survey and academic data for the purposes of this research.

Instructional Guide

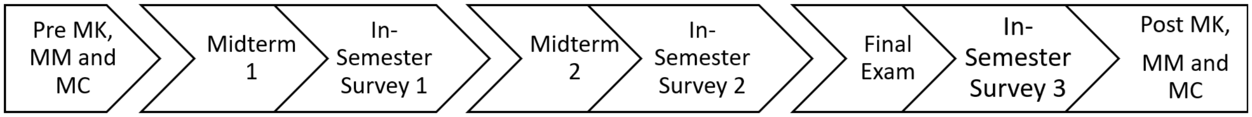
The instructional guide consisted of a calendar for the semester with daily activities recommended for meaningful engagement with the course outside of scheduled class contact time (Supplementary 1). We also included a series of lesson-specific short answer questions that students could use for self-testing and recall. This evidence-based learning calendar relied on four key cognitive learning principles. Successive relearning describes the study strategy where spacing and chunking are used to allow the brain to integrate what is being learned and to have it effectively anchored (Dunnloski & Rawson, 2015). Self-testing and recall helps students identify any gaps in existing knowledge and flag those for deeper learning (see Dunnloski & Rawson, 2015). Teaching as a tool for learning encourages students to work in groups by preparing in advance to present to each other, identify areas of confusion, and study to integrate concepts. Delayed feedback causes students to achieve greater subsequent performance on concepts that are retested (Mullet et al., 2014). The calendar integrated these over the full semester, notifying students, for example, when to review the feedback from each of their quizzes, or when to study in a group for an upcoming midterm exam. This instructional guide was posted on the navigation menu on the main home page of the online platform for the course.

On the first day of the course, students were given an introduction to the online platform including the instructional guide with recommendations on how to use it. At three other occasions during the semester and approximately one week before the upcoming examinations, the instructor referred to the instructional guide and the self-testing questions.

Data Collection

Students were invited to complete two sets of surveys throughout the semester (Figure 1). The first survey set was adapted from the Metacognitive Awareness Inventory (MAI) (Schraw & Dennison, 1994). This inventory consisted of 52 true or false questions which pertained to either MM, MC, or MK. This metacognitive inventory was administered once in the first week of the semester and then again following the completion of the final exam. The second survey set was a researcher-created questionnaire which asked students to report their use of the instructional guide. We also included a question regarding their level of anxiety surrounding the assessment, because anxiety is prevalent in undergraduate students and can impact performance (Rana & Mahmood, 2010; Vitasari et al., 2010). This in-semester survey was administered at three timepoints throughout the semester, immediately following each of the two midterms and the final exam in the class. Grade data were collected from the instructor with the students' consent.

Figure 1
A Timeline of the Semester



Note. The pre- and post- MK, MM and MC scales were distributed at the beginning and end of the semester respectively. The in-semester surveys were distributed directly after each of the two midterms and the final exam.

Data Analysis

Data from respondents who had failed to complete one or more of the surveys were eliminated from the analysis as were those respondents who did not consistently prepare for the three examinations the same way (i.e., either used or did not use the instructional guide all three times). This resulted in 61 individuals (n=61) being included in total.

Data from the pre-and post- semester metacognitive scales were aggregated into a pre- and post-score on MM, MC, and MK. Midterm one grades were subtracted from midterm two grades, and midterm two grades were subtracted from final exam grades to obtain measures of improvement from each exam to the next. These data, in addition to exam grades, self-reported use of the instructional guide, and survey responses about feelings of anxiety, were then entered into R Studio 1.1.3 statistical program (RStudio Team, 2016).

The impact of the interactions between the use of the instructional guide and the timepoint on each MK, MM, and MC were tested using a 2 x 2 mixed design ANOVA. Similarly, a mixed design ANOVA was used to test the interactions between instructional guide use and timepoint on both absolute performance and performance relative to previous assessments. A mixed design ANOVA was chosen to account for both the between-subjects variable of instructional guide use and the within-subjects variable of timepoint across the semester.

We used an independent t-test to compare improvement from the first assessment to the final exam between the two groups (students who did vs. students who did not use the instructional guide). A repeated measures ANOVA was used to test if there was a relationship between anxiety and grades over time.

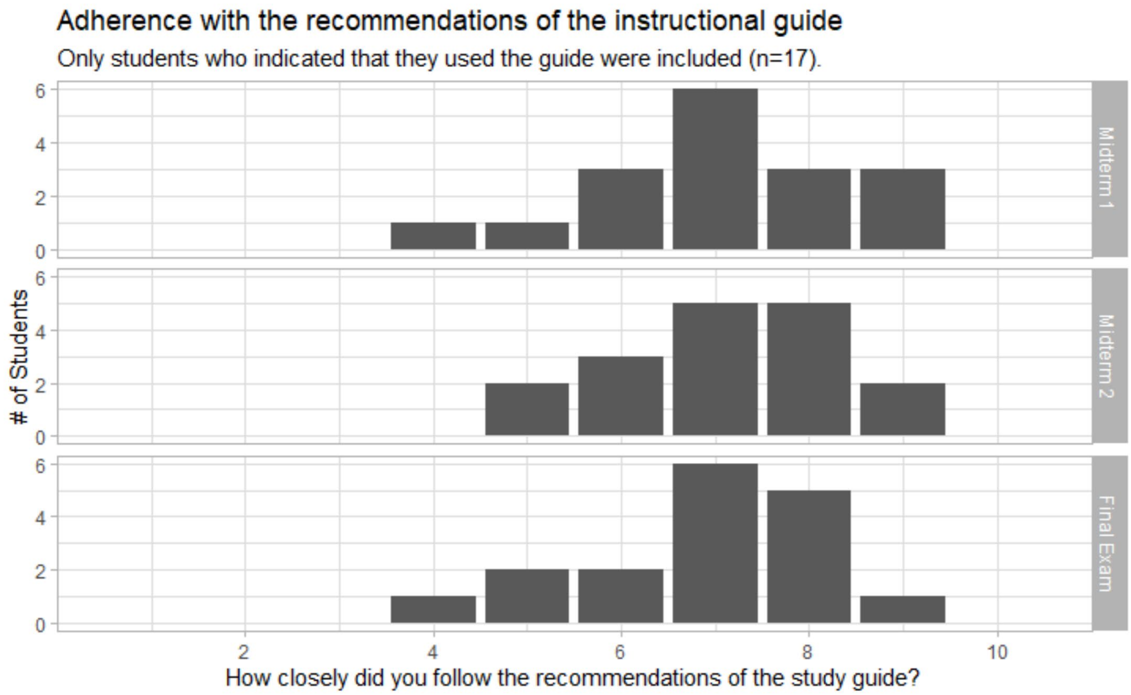
Given the unexpected finding of a negative relationship between use of the instructional guide and absolute exam performance, we also explored assessment anxiety as a mediating factor by using an independent t-test to compare anxiety across the two groups of students.

Results

Use of the Instructional Guide

Students who reporting having consistently used the instructional guide (n=17) were asked to rate their adherence to the guide on a ten-point scale (1= almost no adherence to 10=full adherence). They rated their adherence to the recommendations of the instructional guide as being 7.06 ± 0.33 (mean ± standard error), 7.12± 0.29 and 6.81±0.32 out of ten on each midterm one, midterm two and the final exam respectively (Figure 2). A within-subjects ANOVA revealed no significant difference in adherence to the study guide between the three examinations. 44 students reported having not used the instructional guide.

Figure 2
A Histogram of Student Responses (n=17) about Study Guide Use



Note. The histogram represents students' responses to the question "How closely did you adhere to the recommendations of the instructional guide?" on a scale of 1-10 for each of the two midterms and the final exam. No significant difference across the three timepoints was revealed.

Instructional Guide and Metacognitive Skills

A 2 × 2 mixed design ANOVA with a between-subjects factor of instructional guide use (yes vs. no) and a within-subjects factor of timepoint (pre- and post-?) revealed that the interaction between instructional guide use and timepoint on MK was not significant. However, there was a significant relationship between the instructional guide use and MK ($F(1,59) = 4.91$, $p = 0.03$), indicating that the MK of those who chose to use the instructional guide was higher than those who chose not to use the instructional guide across timepoints.

Similarly, we used a 2 × 2 mixed design ANOVA with a between-subjects factor of instructional guide use (yes vs. no) and a within-subjects factor of timepoint (pre- and post-?) to test if there was a relationship between use of the instructional guide and MC over time. The interaction between instructional guide use and timepoint on MC was not significant, and there was a significant effect of both instructional guide use, $F(1, 59) = 4.08$, $p = 0.05$ and timepoint, $F(1,59) = 4.70$, $p = 0.03$, such that the MC of those who chose to use the instructional guide was consistently higher than those who chose not to use the instructional guide, and that MC scores decreased from the pre- test to the post-test.

The same analysis was conducted a third time to test if there was a relationship between use of the instructional guide and metacognitive monitoring over time, revealing only a significant effect of timepoint on MM ($F(1,59) = 5.39$, $p = 0.02$) such that MM scores tended to decrease from the pre- test to the post-test, without evidence for a relationship between instructional guide use and MM.

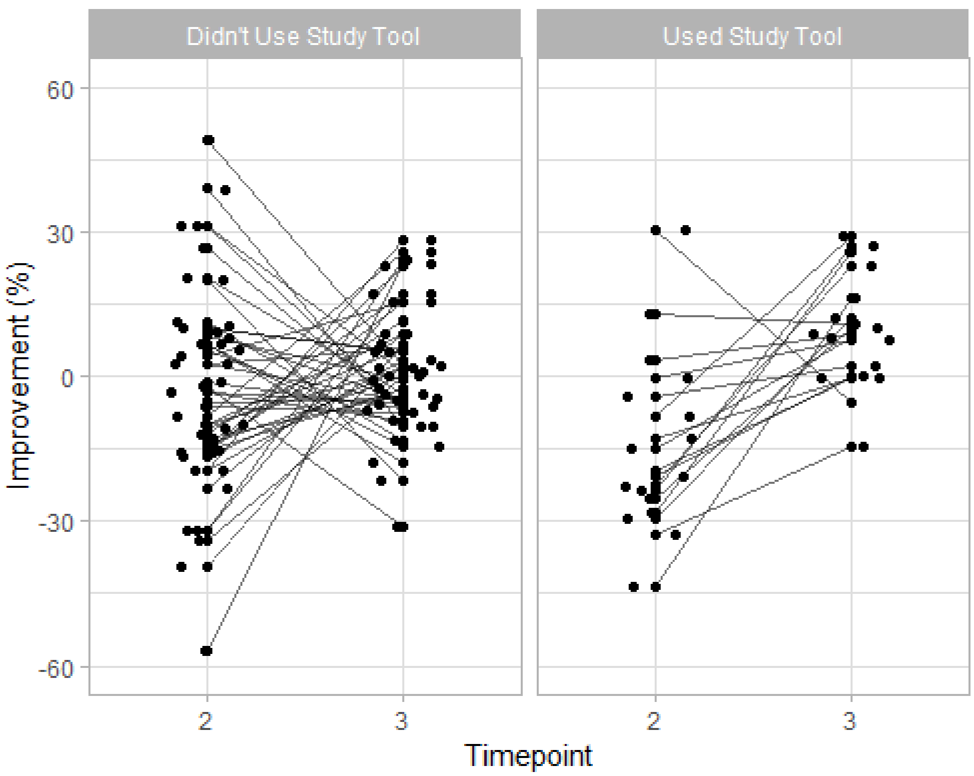
Instructional Guide and Grades

A 2 × 3 mixed design ANOVA with a between-subjects factor of instructional guide use (yes vs. no) and a within-subjects factor of timepoint (1, 2, or 3) revealed a significant relationship between the instructional guide and grade ($F(1,59) = 11.5$, $p=0.001$) and timepoint and grade ($F(1,59) = 3.84$, $p=0.02$) with Tukey Honest Significant Difference (HSD) pairwise comparisons indicating that students who used the instructional guide tended to receive lower grades overall (Prediction 4), and that overall students tended to experience a dip in grades at midterm two.

When the same analysis was conducted to look at improvement in grades since the previous exam, a statistically significant interaction was revealed ($F(1,59) = 5.30$, $p=0.02$). Simple main effects analysis showed no significant changes in improvement for students who chose not to use the instructional guide between midterm one to two (mean improvement= -2.69%) and midterm two to the final exam (+2.57%; $p=0.09$); however, students who did use the instructional guide showed a significant decrease between midterm one to two (mean improvement= -12.08%) and a significant improvement from midterm two to the final exam (+10.14%; p=0.001) (Prediction 5; Figure 3).

Figure 3

A Jittered Scatterplot of Students' Percent Improvement across Timepoints



Timepoint two represents the improvement from midterm one to midterm two, and timepoint three represents the improvement from midterm two to the final exam. Here, a statistically significant interaction was revealed ($F(1,59) = 5.30$, $p=0.02$). Simple main effects analysis showed no significant changes in improvement for students who chose not to use the instructional tool ($p=0.09$), however students who did use the instructional guide showed significantly greater improvement over time ($p=0.001$).

Improvement from midterm one to the final exam was then compared between the two groups using an independent t-test, which revealed no significant differences in total improvement between those who used the instructional guide (mean improvement from midterm 1-3 = -4.63%) and those who did not (-1.44%; $t(28)= -0.59$, $p= 0.6$).

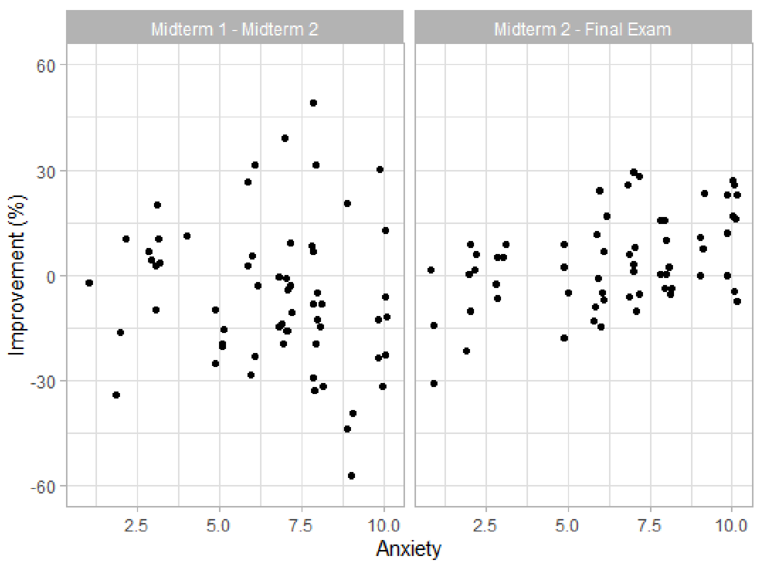
Anxiety and Grades

We used a repeated measures ANOVA to test if there was a relationship between anxiety and grades over time. Analysis revealed a marginally significant interaction between anxiety and timepoint, $F(2, 117)=2.58$, $p=0.08$ and a significant effect of both anxiety, $F(1, 57) =43.6$, $p<0.0001$ and timepoint, $F(1, 117) =4.00$, $p=0.02$, such that grades decreased as anxiety increased and grades improved over time.

When the same analysis was conducted to test if there was a relationship between anxiety and improvement over time, analysis revealed a significant interaction, $F(1,58) =4.87$, $p=0.03$). Because the interaction was significant, we analyzed the time points separately. Simple main effects analysis showed no relationship between anxiety and improvement from midterm one to two ($p=0.25$), however improvement between midterm two and the final exam was significantly positively related to anxiety such that students with greater anxiety improved more ($p<0.0001$; Figure 4).

Figure 4

A Jittered Scatterplot of Anxiety Level by Improvement Between Each Exam



Here, we found a significant interaction between anxiety and improvement over time, $F(1,58) =4.87$, $p=0.03$). Simple main effects analysis showed no relationship between anxiety and improvement from midterm one to two ($p=0.25$), however improvement between midterm two and the final exam was significantly positively related to anxiety such that students with greater anxiety improved more ($p<0.0001$), indicating that assessment anxiety may be beneficial when the assessment is higher stakes.

Discussion

The goal of this research was to determine if an online instructional tool that guided students into evidence-based studying behaviours could effectively teach metacognitive knowledge, thereby affecting metacognitive control, metacognitive monitoring, and exam performance. The results of this study showed that use of an online instructional guide was related to higher scores on MK and MC; however, given that this difference existed even at the beginning of the semester, it is likely that it does not reflect an impact of the instructional guide, but rather an initial difference between the two groups. That is, students with higher MK and MC at the beginning of the semester were more likely to opt to use the instructional guide. Given the skills implied by higher MK and MC scores (i.e., strong procedural knowledge about the relative effectiveness of different study strategies (MK), and heightened ability to make judgements and choices about learning (MC)), it follows that students with these traits would be more likely to recognize the usefulness of an instructional guide and make the judgment to consult such a guide when studying.

No changes in MK over time were found; however, there were significant declines in MM and MC scores from the pre- to post-tests for those who used the online instructional guide. This negative relationship between guide use and MM and MC scores was unexpected; however, it may be explained by students becoming more knowledgeable about their skills relative to others over time. The MM and MC scores achieved on the pre-test were uniformly high, indicating that most students believed that they were aware of their learning and doing everything they could to improve. Given that past literature has indicated that most students have poor overall metacognitive abilities (Ehrlinger et al., 2008; Lewine & Sommers, 2016; Saenz et al., 2017), and assuming our sample is representative, it is possible that these initial self-reported scores were inflated. It is therefore likely that introspection throughout the semester led the students to reassess their responses when completing the post-test, resulting in lower scores. This finding may be in part due to the nature of the scale as a dichotomous true or false response. Here, students may select "true" simply because they can recall a single instance of the behaviour, resulting in inflated scores. As students learn more about their peers' study habits, they may reassess the frequency of their own behaviours against a new comparison group, resulting in a different response trend. Given the inflated scores on the pre-tests, we are thus unable to make conclusions about the impact of the online instructional guide on the various aspects of metacognition.

Analysis of absolute exam performance showed that, on average, students experienced a dip in grade on the second midterm. According to the instructor of the course, this finding is consistent with past course offerings and has been attributed to a more difficult topic. Perhaps more interestingly, our findings showed a negative relationship between use of the instructional guide and absolute exam performance. This finding was unexpected. Therefore, to better understand this result, we explored assessment anxiety as a mediating factor. Anxiety about an assessment was shown to be negatively related to performance, which corroborates previous findings in the literature (Rana & Mahmood, 2010; Vitasari et al., 2010). When we examined the relationship between anxiety and use of the online instructional guide, we found that students who reported greater anxiety were also significantly more likely to report having used the instructional guide, ($t(242)=4.2$, $p<0.001$). This, combined with our finding that anxiety is negatively related to performance, therefore provides a mechanism for the finding that higher use of the intervention was associated with poorer exam performance overall. This finding indicates that anxiety may be related to the choices students make while studying; in this case, students who were feeling highly anxious about the assessment were more likely to access resources to assist them in their studying. However, perhaps due to their anxiety, these students still had lower absolute performance compared to less anxious peers and/or than their peers who chose not to use the study guide.

When performance was considered in terms of improvement over time, we saw a more interesting trend. While all students showed about the same amount of improvement from the first midterm to the final exam, we did find compelling evidence of a much greater improvement between the midterms and the final exam for those students who used the online instructional guide. Furthermore, while those who did not use the instructional guide showed various performance profiles, students who chose to use the guide showed nearly uniform improvement between the second midterm and the final exam (see Figure 3), where there was arguably more at stake. Indeed, of those who used the guide, only two students showed a decline in performance between the two assessments. This finding indicates that the use of the instructional guide and feelings of anxiety may be beneficial in some instances, particularly for high-stake assessments.

One limitation of this study is that we did not collect data about the mediating factor of studying. While students who used the instructional guide indicated that they adhered to its guidelines, we were unable to assess how this actually impacted their studying. It would have been interesting to further understand how students were engaging with the guide and if the quality of that engagement changed over time. That is, students that indicated that they had used the instructional guide and adhered to its guidelines may still have had differing levels of success in employing the study strategies they were learning about. Furthermore, a change in how students were using the instructional guide would help to explain why students who had done so poorly on the second midterm were able to improve for the final exam. Their poor grades on the second midterm, combined with the emphasis placed on the final exam grade, may have prompted students to engage more effectively with the guidelines set out by the instructional tool.

Conclusion

These findings provide some evidence for the benefit of an online instructional guide on student performance. However, because students self-selected to use the instructional guide, we are unable to make conclusions about the impact of the guide in isolation. Rather, our research suggests that students who are more anxious about an assessment are more likely to make use of instructional support resources, and that use of those resources is most likely to have an impact on high-stake assessments such as the final exam. We speculate that this greater impact may have been a result of more in-depth engagement with the guide in advance of the final exam. We did not assess the ways in which students studying may have changed over the course of the semester. We recommend that future research assess exactly how students chose to use the instructional guide over the course of the semester and explore more active methods of providing lessons on MK, MM and MC to ensure that all students will use the opportunities provided by the course design to benefit maximally from the instruction.

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