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| Research Article

# All "wrapped" up in reflection: supporting metacognitive awareness to promote students' self-regulated learning

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**ABSTRACT** Self-regulated learning (SRL) is the process of utilizing effective strategies to acquire knowledge or skills and is influenced by motivation, metacognitive processing, and study-related behaviors. We hypothesized that by using survey tools that allow reflection on and refinement of students' study strategies, we could nurture metacognitive skill development, encourage positive motivation and study-related behaviors, and hence promote academic success. Undergraduate students in a semester-long, second-year biology course were provided with resources to promote SRL and three survey instruments that encouraged them to create study plans and reflect on the effectiveness of their study strategies. Using a student-partnered approach, we sought to investigate the role of metacognition, motivation, and study-related behaviors on academic performance by (i) identifying the self-regulated learning strategies most utilized by students, (ii) investigating the role of reflection in enhancing metacognitive processing and academic performance, and (iii) understanding whether students created and/or modified their study strategies as an outcome of self-regulation. Survey responses allowed us to understand the repertoire of study strategies used by students. Our analyses suggest that students demonstrated metacognitive skill development through the use of the resources and reflection instruments, as they accurately reported on the effectiveness of their study strategies and indicated future plans to shift study-related behaviors from passive to active reviewing techniques. Students across the grade spectrum perceived the reflection instruments as beneficial in identifying areas of improvement and developing long-term study habits, suggesting that these instruments were effective in promoting metacognitive skill development for a variety of student learners. We conclude that supporting students with resources that promote SRL and providing opportunities for timely reflection can promote metacognitive skill development, a key feature of academic success.

**KEYWORDS** self-regulated learning, exam-wrapper, metacognition, academic performance, reflection, study strategies, biology education

Metacognition, motivation, and study-related behavior modifications collectively play a central role in developing self-regulated learning (SRL), which helps improve academic performance (Fig. 1) (1–4). Metacognitive processing is one of the major determinants of effective student learning (5–8 ), and is the ability to understand the extent of one's understanding by, for instance, reflecting on the effectiveness of the learning strategies employed (9). This processing requires students to first monitor and reflect on their learning and then strategically employ a curated set of learning strategies relevant to their monitoring and reflection (e.g., active learning strategies, behavioral strategies, motivational strategies) (10–12). In this study, we describe the first factor as metacognitive processing and the second factor as metacognitive skill development. One measure of metacognitive processing can be through the assessment of

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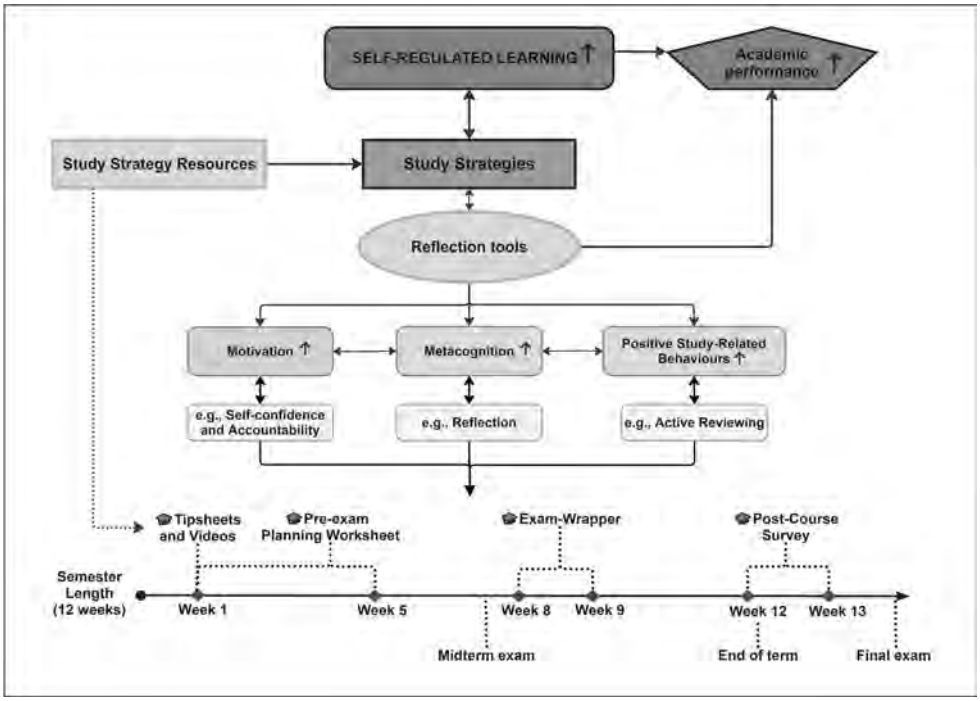


**FIG 1** Study goals and research approach. The overarching goal of this research was to promote SRL, which has been linked to improved academic performance. To accomplish our goal, study strategy resources and reflection tools were created using a students-as-partners approach. The hat symbol represents the resources and tools created for this study. We hypothesized that by using tools that allow for reflection and refinement of students' study strategies, we could promote SRL through positive impacts on intrinsic motivation, metacognitive development, and effective learning behaviors, in a foundation biology course. The timeline illustrates our research process in which reflection tools were provided to students at critical points in the 12-week semester.

metacognitive accuracy, whereby an individual's metacognitive judgments are assessed relative to the actual outcome (i.e., measuring the extent to which a student can predict their grade on an assessment) (12, 13)). Study-related behaviors can be described as the actions individuals take as they pertain to their learning. These behaviors can be used to guide metacognitive processing and SRL (2, 3 ). Student motivation has been described by many different models (14–16). However, in the context of SRL, it is described as the motivation needed to initiate, change, or regulate a particular process or task (17–19). All three factors—metacognition, study-related behaviors, and motivation—contribute to SRL and can influence academic performance (Fig. 1) (1–4).

Self-regulated learners actively judge their needs with or without external help, enabling them to formulate personal learning objectives, determine the resources needed to achieve them and implement appropriate learning strategies (20). Studies indicate that when students are asked to reflect on the effectiveness of their study strategies, metacognitive skill development occurs (1, 21, 22 Qualitative data analysis). However, not all undergraduate students possess a repertoire of effective learning strategies or may incorrectly believe their current practices are effective (3, 8, 23, 24). Thus, it is important that instructors of introductory courses help students develop their repertoire and nurture metacognitive processing through reflection (25, 26). Encouraging reflection through the use of purposefully designed instruments hones metacognitive skills, resulting in effective SRL and allowing students to succeed academically in numerous disciplines (3, 27–32). In addition, analysis of student reflections can help educators develop a broader understanding of study strategies that might help students learn best (26, 33).

In this study, three unique reflection tools were designed and utilized in an online iteration of a second-year, 12-week foundational Cell Biology course at the University of Toronto Scarborough (UTSC): a Pre-exam Planning Worksheet, an Exam-Wrapper, and a Post-Course Survey. Surveys were administered at three key points during the semester (Fig. 1). Student-created study resources were created and administered to students at the beginning of the semester as well.

## Student-created study resources

Resources in the form of tipsheets (Appendix 1) and videos (Appendix 2) were provided to students prior to the Pre-exam Planning Worksheet. These resources were created by undergraduate alumni of the course in consultation with faculty instructors, consistent with our student-partnered approach (34, 35). To increase resource accessibility and student engagement, the resources were presented in both infographic and video format. The resources exposed students to a variety of effective study strategies and acted as a point of reference when completing the Pre-exam Planning Worksheet. Students could use these resources to create or modify a study plan for the semester (Pre-exam Planning Worksheet), reflect on this plan following the midterm exam (Exam-Wrapper), and consider the overall effectiveness of their study strategies at the end of the course (Post-Course Survey).

### *Reflection tool 1: Pre-exam Planning Worksheet*

"Pre" tools are instruments used any time prior to the first exam. They have been used to help metacognitive skill development by providing opportunities for students to set goals and prepare study plans (4, 32, 36). Existing examples of these tools indicate the following benefits: improvements in academic performance based on grades (1, 4, 30, 36), the ability to maintain full course loads (37), and measured reductions in negative effects (such as decreased concentration, anxiety, stress, and general feelings of sadness) (31). The Pre-exam Planning Worksheet prompted students to reflect on study strategies they had used in the past, consider the resources provided, and create or modify study plans for the semester ahead.

### *Reflection tool 2: Exam-Wrapper*

Exam-Wrappers are well documented as tools that accompany major assessments to encourage students' self-evaluation and reflection (38, 39). Using this tool, students can reflect on their exam preparation and performance, predict their grades, and make modifications to their study strategies as they prepare for the next evaluation (40). Studies have shown that having enhanced awareness of the effectiveness of one's learning strategies can motivate self-improvement (6, 38, 41). We distributed an Exam-Wrapper immediately following the midterm exam (Fig. 1). The Exam-Wrapper asked students to reflect on the effectiveness of their preparation, factors contributing to their perceived performance, and modification of their study strategies for future learning (39, 42).

### *Reflection tool 3: Post-Course Survey*

A Post-Course Survey, conducted toward the end of the course, is a reflection tool that complements institutional course evaluations. Traditionally, such instruments focus on student performance with respect to the instructor's benchmarks (43, 44). In 2013, Lovett et al. proposed a new type of Post-Course Survey prompting students to reflect on exam preparation, types of errors made on the exams, and adjustments for future learning (45). Our Post-Course Survey tool asked students to examine their overall performance with respect to their learning strategies and whether they thought these reflection tools promoted effective SRL.

We explored students' SRL strategies and metacognitive abilities using three research questions:

1. Which of the study strategies or combinations of strategies did students utilize most? How did these strategies affect metacognitive processing and academic improvement?
2. Are these reflective tools (Pre-exam Planning Worksheet, Exam-Wrapper, and Post-Course Survey) effective in enhancing metacognitive processing?
3. Did students create or modify their study plan by utilizing one or more study strategies from the provided resources (tipsheets/videos)? Did these modifications correlate with academic improvement in the course (course grades)?

We hypothesized that by promoting reflection using tools allowing for refinement of students' study strategies, we could promote SRL, and hence academic success in a foundation biology course. We hope our findings and recommendations will aid other instructors' efforts in honing metacognitive skill development and supporting the academic success of undergraduate learners.

## METHODS

### Survey instruments and study design

The three survey instruments used in this study were designed by a team of undergraduate and graduate students along with faculty instructors, aligning with literature on S*tudents as Partner*s in higher education (34, 35). These instruments were implemented in a second-year, 12-week semester-long Cell Biology course at UTSC in Fall 2021 (University of Toronto Research Ethics Board approved human subjects research protocol #41565). All 351 enrolled students were invited to participate in our research study. Survey instruments were distributed online *via* the course's learning management system (Quercus) and were graded for completion (1% of the final course grade for each completed survey). Although the surveys were a mandatory course component, participation in the research study was not, and hence, informed consent was sought from students. In all, 254 students provided consent and completed the Pre-exam Planning Worksheet, 210 completed the Exam-Wrapper, and 191 completed the Post-Course Survey. To acquire a representative view of the entire semester, only responses from students who completed all three instruments were included in our analyses, amounting to an $n$ = 191 (54.4%) response rate. Irrelevant and indecipherable responses were excluded from our data analysis. In addition, as some questions on the survey asked students to describe their use of study strategies throughout the semester, there could be multiple mentions of different study strategies ($n$ = 229) contained within each student response ($n$ = 191). Therefore, to reflect a more accurate representation of our data, each of the mentions of study strategies used was presented in our analyses, rather than total student responses.

In week 1, students were provided resources (Appendices 1 and 2) outlining effective study strategies and were encouraged to apply them to their learning. The Pre-exam Planning Worksheet (Appendix 3) was available from weeks 1 to 5. The Exam-Wrapper survey (Appendix 4) was provided immediately following the completion of the midterm exam (week 8) and was available for 1 week. The Post-Course Survey (Appendix 5) was available in the final week of the semester (week 12) for 1 week (Fig. 1).

### Qualitative data analysis

De-identified qualitative responses were analyzed using NVivo 12 (https://www.qsrinternational.com/nvivo-qualitative-data-analysis-software/home) (46). A hierarchical structure of response-sorting categories (i.e., nodes and sub-nodes) was developed for each instrument to code student responses (Appendices 6–8). These node structures were organized around the three main components of the SRL model: *Behavior, Metacognition,* and *Motivation* (2). Coding guidelines were developed through the

team-based coding of a subset of responses, and subsequent coding was divided equally among four coders of the research team. Coding inter-rater reliability was assessed twice a month throughout the coding process by individually coding the same five entries. Average inter-rater reliability scores were 0.71, 0.70, and 0.82 for the Pre-exam Planning Worksheet, Exam-Wrapper, and Post-Course Survey, respectively.

### Quantitative analyses

Some responses were coded under multiple nodes in our qualitative analyses, as they related to multiple SRL axes. Our numerical calculations, representing frequency, were based on the number of total coded responses rather than the number of completed surveys. All statistical analyses were performed using R version 4.0.5 (47–51). Raw data and R code are available at https://github.com/sapolnach/StudyStrategies. As a measure of academic improvement throughout the semester, we analyzed student's exam test scores (as percentages) by calculating the difference between the midterm and final exam (Final exam score − midterm exam score = grade change). These resulting differences were categorized into three grade ranges to reflect students who demonstrated little to no improvement or decreased academic performance (<5% grade change), relative improvement from the midterm exam to the final exam (5%–24% grade change), and significant improvement from the midterm exam to the final exam (≥25% grade change). We employed a one-way ANOVA or independent samples *t*-test to examine the differences in academic improvement among different student respondent groups. As grade changes were not normally distributed as assessed by Shapiro-Wilks normality tests, all ANOVAs and independent-sample *t*-tests were verified using a bootstrapping procedure (9,999 bootstrap samples).

## RESULTS

### Research question 1: Which of the study strategies or combination of strategies did students utilize most? How did these strategies affect metacognitive processing and academic improvement?

We coded students' survey responses to understand the range and prevalence of study strategies that were used in the context of this foundation course. As illustrated in Fig.

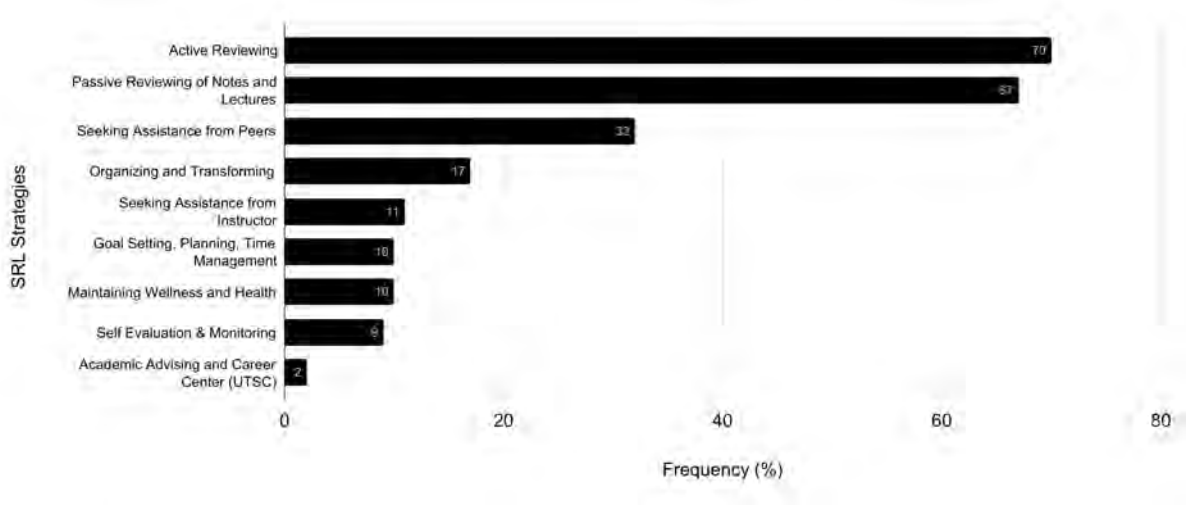


**FIG 2** Students utilized a variety of SRL strategies. SRL strategies used for midterm exam preparation, as reported on the Exam-Wrapper, are shown in descending order of appearance in student responses. The majority of student responses alluded to both *active* (70%) and *passive reviewing* (67%) strategies, while *self-evaluation and monitoring* (9%) and *utilizing the Academic Resource and Career Center of the University of Toronto* (2%) were the least reported. The percentage values represent the proportion of responses that cited each of these strategies in the 191 responses received. A description of these SRL strategies can be found in the supplementary material (Appendix 1).

2, the most extensively used study strategies reported by students were *Active Reviewing* and *Passive Reviewing of Notes and Lecture Slides*. The majority of coded responses (70%, *n* = 191) indicated that students used *Active Reviewing,* while *Passive Reviewing of Notes and Lecture Slides* was cited in 67% of responses (*n* = 191).

To investigate the academic impact of the study strategies that students chose to employ most, we analyzed students' Exam-Wrapper reflections and correlated them with their midterm grades. As shown in Fig. 3A, 52.6% (*n* = 135) of students reported their strategies to be *Moderately Effective*. Of these, 16 respondents received a grade in the 81%–90% range (Fig. 3B). 27.4% of respondents (*n* = 135) indicated their strategies were *Very Effective* (Fig. 3A). Of these, 10 students received a grade in the 81%–90% range (Fig. 3B). 20% of respondents (*n* = 135) indicated that their study strategies were *Not Effective* (Fig. 3A), and of these respondents, two scored in the grade range of 81%–90% (Fig. 3B).

Another measure of students' metacognitive processing was the ability to accurately predict exam grades after reflecting on their preparation (12, 13). In the Exam-Wrapper, students were asked to predict their midterm grades based on their perceived midterm performance. The largest proportion of respondents (36.6%, *n* = 180) suggested a grade in the 71%–80% grade range (Fig. 4A). 26.1% of respondents suggested a grade in the 61%–70% grade range, and 17.7% of respondents suggested a grade in the 50%–60% grade range. Only 16.7% of respondents suggested a grade in the 81%–90% grade range. We then compared these predicted grades with the actual midterm exam grades (Fig. 4B). In total, 102 students (56.7%, *n* = 180) predicted a grade within ±10 points from their actual scores, with 56 students of these 102 (54.9%, *n* = 102) underestimating their grade by ≤10, and 46 students (45%, *n* = 102) overestimating their grade by ≤10.

On the Post-Course Survey students were asked which study strategies they found most effective. The top five strategies respondents (*n* = 191) classified as effective were as follows: *Active Reviewing* (74.4%), *Passive Reviewing* (45.0%), *Goal Setting, Planning, Time Management* (23.6%), *Keeping Records* (19.4%), and *Organizing, Transforming* (14.7%) (Fig. 5A). Students were also asked which study strategies they planned to employ in the future (Fig. 5B). The top five study strategies respondents (*n* = 191) intended on adding to their future repertoire were as follows: *Active Reviewing* (66.0%), *Goal Setting, Planning, Time Management* (50.8%), *Self-Evaluation & Monitoring* (29.3%), *Seeking Assistance From Peers* (16.2%), and *Seeking Assistance From Instructor* (15.2%) (Fig. 5B). Overall, *Active Reviewing* was the most effective study strategy reported, and respondents expressed interest in either starting or continuing to use this strategy in the future.

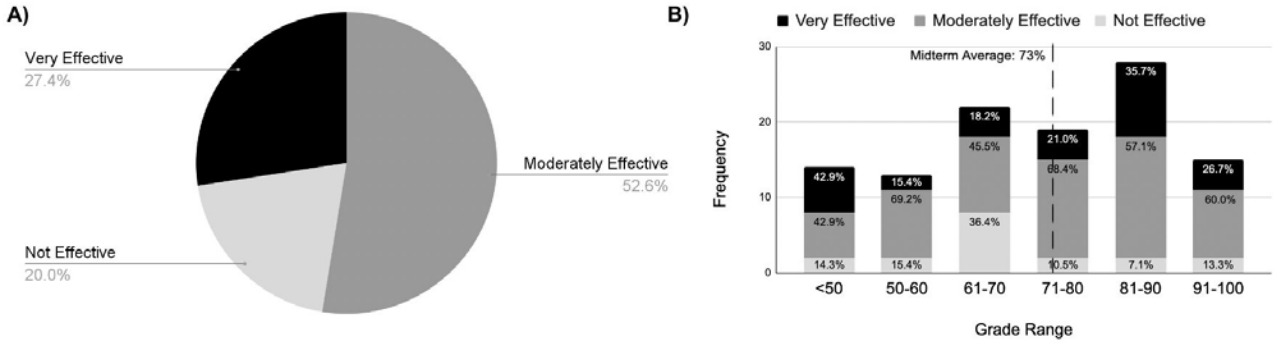


**FIG 3** Students accurately report the effectiveness of their study strategies as demonstrated by correlation with their academic performance. (A) Of the 135 survey responses coded in the Exam-Wrapper, 27.4% of the students found their strategies to be *Very Effective*, the majority of students (52.6%) found their study strategies to be *Moderately Effective*, and 20.0% found them to be *Not Effective*. (B) The correlation of student reports of the effectiveness of their study strategies with their academic performance on the midterm exam was used as a measure of metacognitive abilities. The midterm course average was 73% and of the 28 students who scored between 81% and 90%, 35.7% of the students reported their study strategies to be *Very Effective*, 57.1% of the students reported their strategies to be *Moderately Effective,* and only 7.1% of the students reported their strategies to be *Not Effective*. Conversely, of the 13 students who scored between 61% and 70%, 18.2% reported their strategies to be *Very Effective,* whereas 36.4% of the students reflected that their strategies were *Not Effective*. Students assessed the effectiveness of their study strategies prior to receiving their midterm exam feedback and grades.

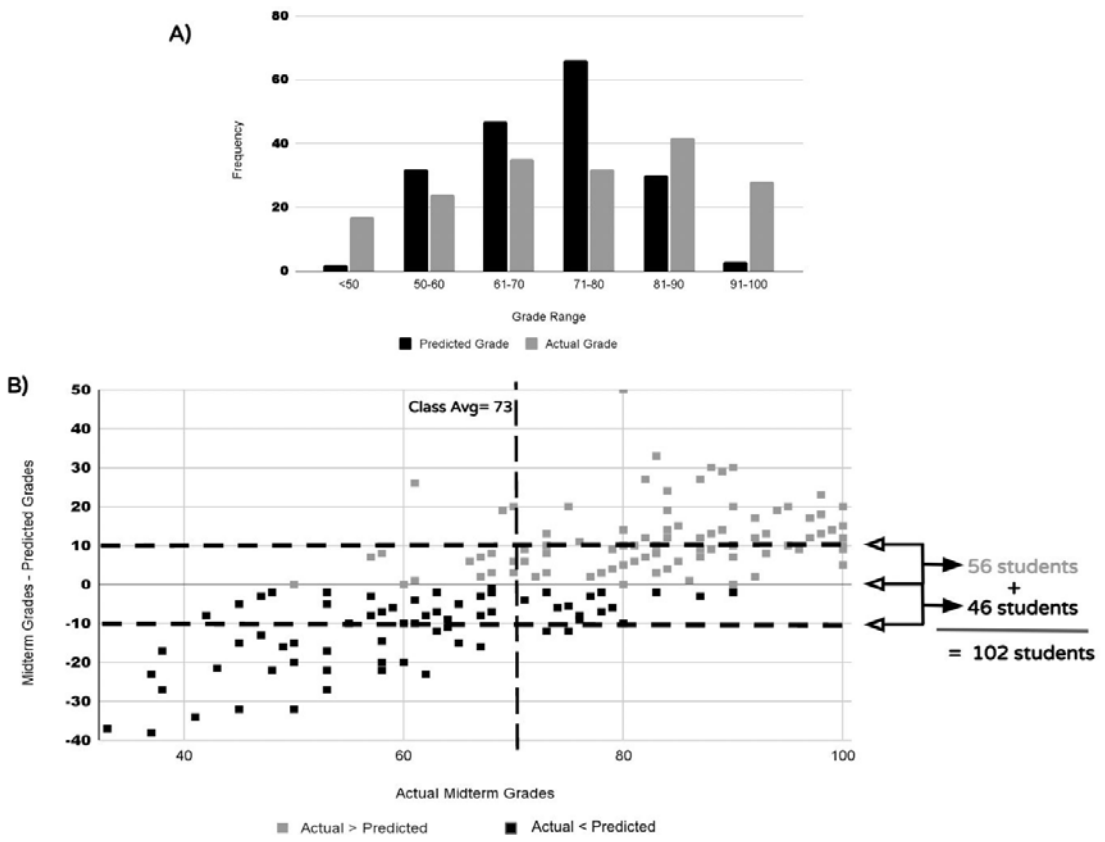


**FIG 4** Students utilized efficient metacognition and reflected on their performance effectively. (A) A normal distribution was observed in the students' self-assigned predicted grades where most students assigned themselves a grade between 71 and 80. As compared to their actual midterm grades, most students received a grade between 81 and 90 with an average of 73. (B) From the 180 student responses collected from the Exam-Wrapper, 102 (56.7%) students suggested a midterm grade that was ±10 points from their actual scores, as represented by the cohort of data points between +10 and −10 on the graph. There is also a positive trend seen among the students, where students with higher midterm grades underestimated their performance, that is, larger positive data set past the midterm average, whereas students with a grade lower than the average suggested a score higher than their actual midterm grades, that is, larger negative data set before the midterm average.

## Research question 2: Are these reflective tools (re-exam Planning Worksheet, exam-Wrapper, and Post-Course Survey) effective in enhancing metacognitive processing?

Next, we investigated the effectiveness of the survey instruments themselves. On the Post-Course Survey, students were asked whether they found the Exam-Wrapper beneficial in identifying areas of improvement and developing effective long-term study habits. Figure 6A shows that 89.5% of respondents ($n$ = 191) found the Exam-Wrapper helpful in identifying areas of improvement when planning or modifying study strategies, whereas 10.5% of respondents ($n$ = 191) reported no benefit. Among respondents who reported benefit, it was commonly suggested that without the Exam-Wrapper they would not have evaluated their study strategies and test preparation methods after an examination (e.g., Appendix 9, Response 14). Academic improvement was assessed as the difference in grade change between midterm and final exam scores and was categorized in a bin distribution system, which was standardized to account for the 5% difference between the midterm and final exam averages (Fig. 6B). There was no significant difference in grade changes between those who reported either *Yes* or *No* to finding the Exam-Wrapper beneficial in identifying areas of improvement [$t$(189) =1.20, $P$ = 0.230, d = 0.285; Bootstrapped $P$ = 0.222].


**FIG 5** The SRL strategies considered by students. (A) SRL strategies students found to be effective in the course, as reported in the Post-Course Survey. (B) Study strategies students would use to support their learning in the future, as reported in the Post-Course Survey. The percentage values represent the proportion of responses that cited each of these strategies in the 191 responses received. A description of these SRL strategies can be found in the supplementary material (Appendix 1).

In the context of developing long-term study habits, the majority of respondents (85.9%; *n* = 191), reported benefiting from the Exam-Wrapper. The respondents who found the Exam-Wrapper effective in developing long-term study habits were often critical of their current study strategies and reflected deeply on their effectiveness and future use (e.g., Appendix 9, Response 53). 14.1% of respondents (*n* = 191) reported no benefit (Fig. 7A). Correlating student responses with grade change data (Fig. 7B) showed no significant difference in academic improvement [$t(189) = 1.00$, $P = 0.317$, d = 0.205; Bootstrapped $P = 0.329$].

### Research Question 3: Did students create or modify their study plan by utilizing one or more study strategies from the provided resources (tip-sheets/videos)? Did these modifications correlate with academic improvement in the course (course grades)?

Next, we investigated whether the resources provided at the beginning of the semester (tipsheets and videos) were useful in creating and/or modifying student study plans throughout the term. The Post-Course Survey included questions evaluating whether

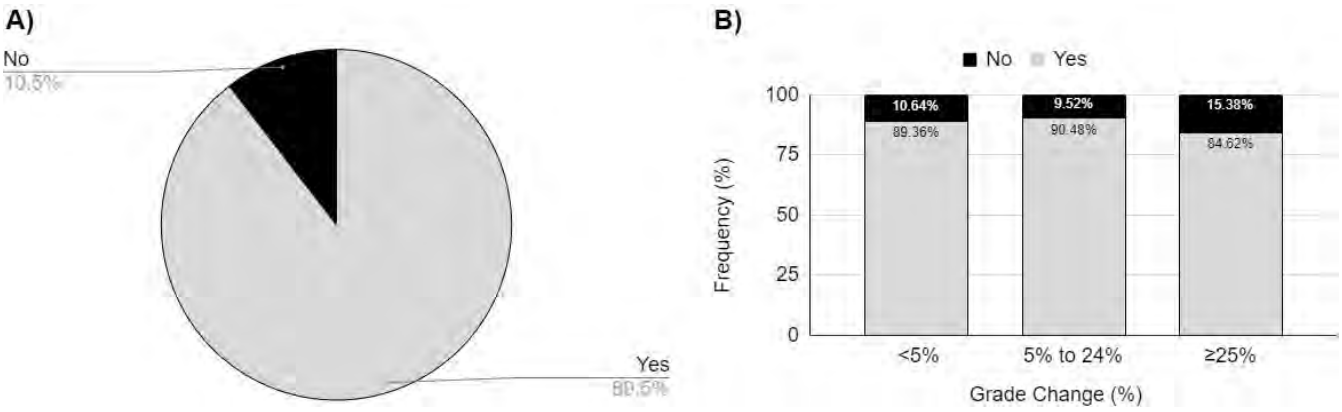


**FIG 6** Students who identified areas for improvement using the Exam-Wrapper fell across the entire academic performance spectrum. (A) Of the 191 survey responses in the Post-Course Survey, the majority (89.5%) responded *yes* when asked if the Exam-Wrapper helped them identify areas for improvement with regard to their test preparation and study strategies. (B) Categorization of these student responses and examining the change in grade between midterm and final exams (left to right: <5% change, 5% to 24% change, ≥25% change) provides a distribution of the overall trend in academic performance in the course, comparing respondents that did and did not find the Exam-Wrapper helpful in identifying areas for improvement. There was no significant difference in grade changes between those who responded *yes* and *no* [$t(189) = 1.20$, $P = 0.230$, $d = 0.285$; Bootstrapped $P = 0.222$].

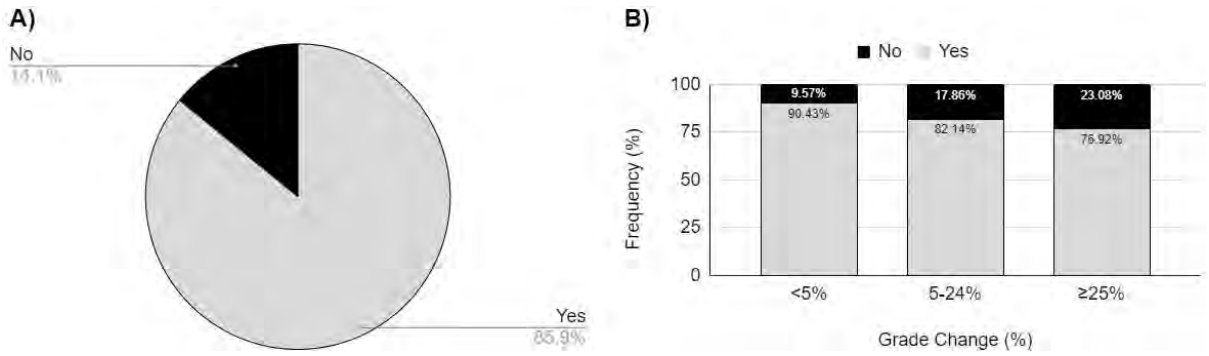


**FIG 7** Students who developed long-term study habits using the Exam-Wrapper fell across the entire academic performance spectrum. (A) Of the 191 survey responses in the Post-Course Survey, the majority (85.9%) responded *yes* when asked if the Exam-wrapper helped in developing long-term study habits. (B) Categorization of these student responses and examining the change in grade between midterm and final exams (left to right: <5% change, 5% to 24% change, and ≥25% change) provides a distribution of the overall trend in academic performance in the course, comparing respondents that did and did not find that the Exam-wrapper helped in developing long-term study habits. There was no significant difference in grade changes between those who responded *yes* and *no* [$t(189) = 1.00$, $P = 0.317$, $d = 0.205$; Bootstrapped $P = 0.329$].

students adhered to or modified their original study plan as reported in the Pre-exam Planning Worksheet. Figure 8A shows that 46.7% of responses ($n$ = 191) indicated they *Adhered* to their original study plan, 25.5% *Partially Adhered*, and 27.7% *Did Not Adhere*. Of the 114 respondents who adhered to their original study plan, the majority of respondents utilized the study strategies outlined in the resources provided (79.8%, $n$ =

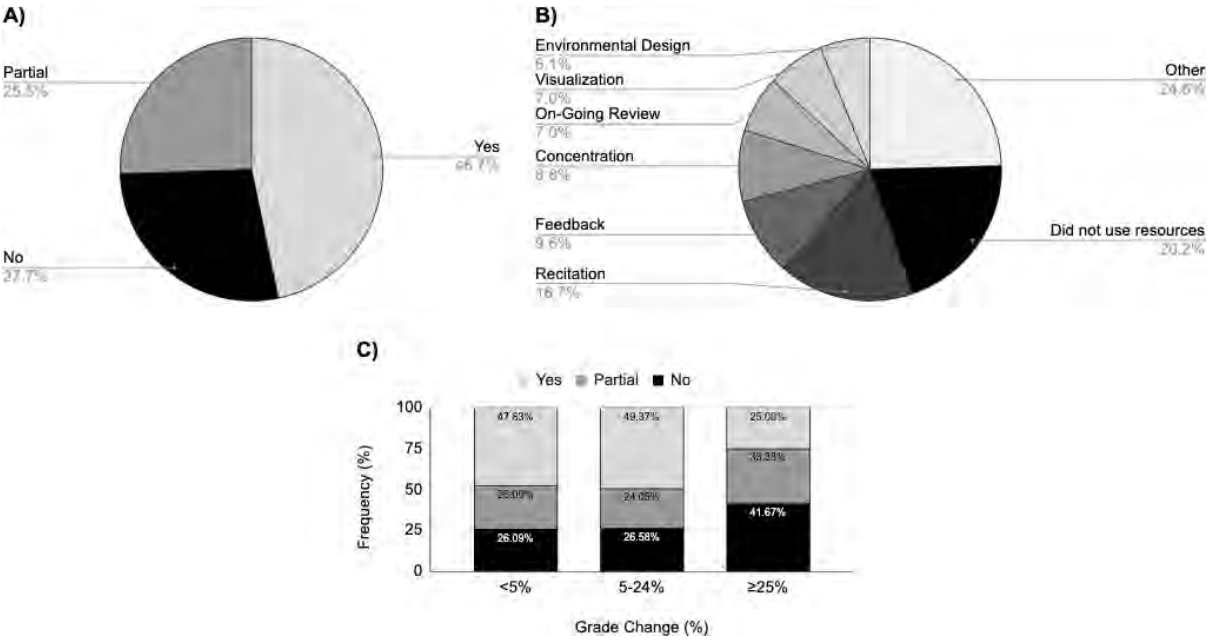


**FIG 8** The majority of students either Adhered or Partially Adhered to a study plan. (A) Of the 184 student responses, 46.7% indicated they had adhered to their original study plan, 25.5% of responses indicated they partially adhered, and 27.7% of responses indicated they did not adhere. (B) Of the 116 students who adhered to their study strategy plan, the majority (79.8%) indicated they used the resources provided. The top three strategies were as follows: *Recitation* (recalling and explaining in your own words), *Feedback* (self-quizzing and asking for help), and *Concentration* (focusing on the task at hand). Other less utilized study strategies (light gray) include strategies such as *Intention, Big and Little Picture, Association, Selectivity, Time on Task, and Elaboration*. 20.2% of responses indicated that they did not use the resources provided. (C) Examining the change in grades between midterm and final exams (left to right: <5% change, 5% to 24% change, and ≥25% change) provides a measure of the overall trend in academic performance in the course, comparing respondents that did, partially, and did not adhere to their original study plan. There was no significant difference in grade change among students who adhered, partially adhered, or did not adhere to their original study plan [$F(2, 188) = 1.25$, $P = 0.290$, $\eta^2 = 0.013$; Bootstrapped $P = 0.329$].

114), while only 20.2% did not use the resources in any capacity (Fig. 8B). The four most cited strategies were as follows: *Recitation* (16.7%), *Feedback* (9.8%), *Concentration* (8.8%), and *On-Going Review* (7.0%) (defined in Appendix 1). *Other* (24.6%) less utilized student study strategies include *Intention*, *Big and Little Picture*, *Association*, *Selectivity, Time on Task*, and *Elaboration*. We next examined whether a modification to study plans impacted students' performance on both midterm and final exams. Figure 8C shows no significant difference in academic performance between students who adhered or did not adhere to their study plan [$F(2, 188) = 1.25$, $P = 0.290$, $\eta^2 = 0.013$; Bootstrapped $P = 0.329$].

While examining the utility of the resources provided to students, we found that the majority of total student responses mentioned the use of the resources provided in some capacity (82.9%; $n = 229$), whereas 17.1% of responses indicated they had not used the resources provided in any capacity (Fig. 9A). The four most cited study strategies from the resources provided were as follows: *Recitation* (17.5%), *Feedback* (10.5%), *Environmental Design,* and *Concentration* (8.8% each). *Other* (21.5%) study strategies students used from the resources include *Visualization*, *Time on Task*, *Selectivity*, *Ongoing Review*, *Intention*, and *Big and Little Picture*. Figure 9B correlates the use of tipsheet resources with grade change data. There is no significant difference in academic performance observed between students who employed the resources and those who did not [$t(189) = 0.64$, $P = 0.523$, $d = 0.107$; Bootstrapped $P = 0.523$)]; however, most students reported using the tipsheet resources in formulating and adjusting their study plan.

Lastly, we investigated students' motivation to study as an important factor influencing SRL. Figure 10 presents a snapshot of student motivation to study during the course. The majority of respondents (81.2%; $n = 191$) indicated that they had struggled with their motivation to study in some capacity while completing the course, whereas only 18.8% of respondents indicated that they *Did Not Struggle Greatly with Motivation*. The five factors affecting study motivation were: *Ineffective Time Management* (25.1%), *Struggled with COVID-19 and Online Learning* (22.5%), *Unable to Maintain Wellness and Lifestyle* (16.8%), *Low Self-Confidence and Accountability* (15.7%), and *Other* (showing a lack of interest in course material) (1.0%).

## DISCUSSION

### Students report a shift toward active reviewing strategies as they consider them more effective

Active reviewing, or recalling information through retrieval practices, improves one's knowledge and retention of the material (52). Passive reviewing practices, such as

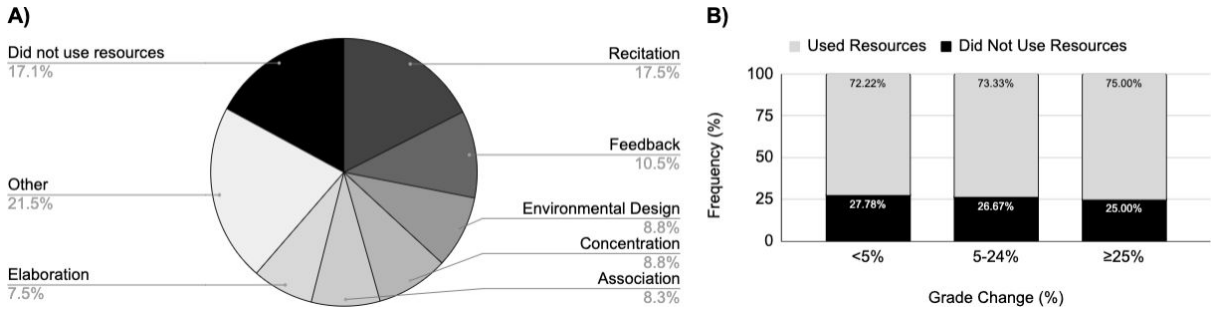


**FIG 9** The majority of students used the study strategy resources provided at the beginning of the semester. (A) Of the 191 student responses reflecting on the use of study strategy resources provided at the beginning of the term, 229 mentions of study strategies were analyzed. The top six strategies were: *Recitation*, *Feedback*, *Environmental Design*, *Concentration*, and *Association*. Other utilized study strategies from the resources provided are indicated in light gray, including strategies such as *Visualization, Time on Task, Selectivity, Ongoing Review, Intention,* and *Big and Little Picture*. 17.1% of coded student responses indicated that they did not use the provided resources. (B) Examining the change in grade between midterm and final exams (left to right: <5% change, 5% to 24% change, and ≥25% change) provides a measure of the overall trend in academic performance in the course, comparing respondents that did and did not utilize the provided study strategy resources. There was no significant difference in grade change between those who responded yes and no, [$t(189) = 0.64$, $P = 0.523$, $d = 0.107$; Bootstrapped $P = 0.523$].

re-reading notes, increase familiarity but not mastery of the material (53, 54). *Active Reviewing* was reported as the most effective SRL strategy by respondents in our study (Fig. 2 and 5). Most students (66.0%) were willing to use active reviewing again, or for the first time to support their future learning (Fig. 5). Congruently, students report a significant decrease in their intent to use passive reviewing strategies in the future (from 45.0% to 10.5%), suggesting that they found this to be a less effective strategy. In addition, we observed an increase in intent to use the strategies *Goal setting, Planning, Time management* (from 23.6% to 50.8%), and *Self-evaluation & Monitoring* in the future (from 7.85% to 29.3%), showcasing student metacognitive skill development and identification of more effective strategies for future learning. This shift in student perceptions of effective study strategies showcases the benefit of using instruments to help students reflect on the utility of their study strategies.

We also observed that as the grades increased, there was a corresponding increase in the number of students who reported that their study strategies were effective; students were hence more metacognitively aware and showed a higher level of metacognitive processing in the higher academically performing groups (Fig. 3B). Students in the 81%–90% grade range acknowledged the enhanced efficacy of their study strategies and were seen scoring higher than the midterm average. On the other end of the spectrum, students within the <50% grade range reported study strategy effectiveness inconsistent with their academic performance (i.e., 42.9% of students in <50% reported their strategies as *Very effective*). While this could imply poor metacognitive awareness, this could reflect a limitation of the instruments, where this cohort of students was unable to actively engage with the tools provided to reflect on their study strategies. According to Smith et al. (2019), students in lower grade ranges tend to require more motivation and incentive to engage with self-reflection instruments. We advocate for the utilization of classroom and tutorial time to allow active engagement with the tools and assign a certain percentage of the overall grade to the completion of the instruments. In addition, a large proportion of students (36.4%) in the 61%–70% grade range acknowledged that their study strategies were not effective, implying metacognitive awareness but perhaps struggled or were unable to develop an effective study plan. This cohort of students would benefit the most from tools that promote metacognitive development. Moreover, 60% of students within the 91%–100% grade range were seen reporting their strategies to be moderately effective, which we hypothesize could be reflective of End-Aversion Bias (indicating a more modest grade result when asked to reflect on performance) (55).

Few students chose *Seeking Assistance from Peers* (5.76% coverage) and *Instructors* (2.62% coverage) as effective strategies. The COVID-19 pandemic limited opportunities for assistance in person before or after lectures. Additional barriers such as internet access, conflicting schedules, and burnout from online learning may have heavily

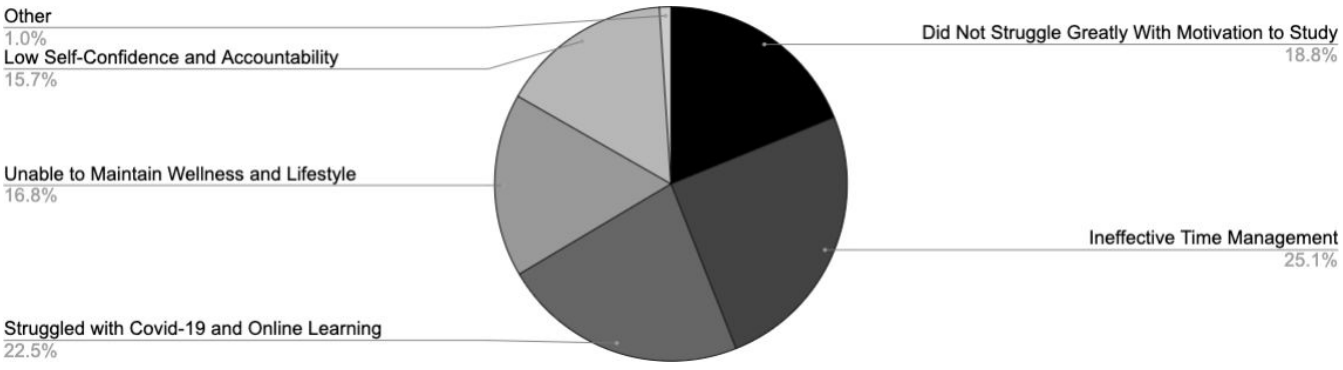


**FIG 10** Snapshot of student motivation throughout the course. From the 191 student responses to the Post-Course Survey, the five factors affecting student motivation throughout the course were as follows: *Ineffective Time Management*, *Struggles with COVID-19 and Online Learning*, *Unable to Maintain Wellness and Lifestyle*, *Low Self-Confidence and Accountability*, and *Other* (showing lack of interest in course material). 18.8% of respondents reported that they *Did Not Struggle Greatly with Motivation to study* throughout the course.

impacted students' access to instructors and peers (56, 57). In our study, 22.5% of respondents explicitly reported a decrease in their motivation to study as a result of online learning and 16.8% reported a decrease in their motivation to study due to burnout as a result of an unbalanced lifestyle (Fig. 10). Importantly, students reported that *Seeking Assistance from Peers* and *Seeking Assistance from Instructor* were strategies they planned to use in the future (Fig. 5).

## Students found the reflection instruments to be valuable tools

Previous studies have demonstrated a positive correlation between goal setting and academic performance (1, 4). We see that a higher percentage of respondents (46.7%) reported that they *Adhered* to their original study plan, while 27.7% of respondents indicated that they *Did Not Adhere* (Fig. 8A). Interestingly, our results do not show a significant difference in academic performance between students that did and did not adhere to their study strategies (Fig. 8C). We hypothesize that this may be due to varying interpretations of instrument questions. We observed that some students who reported that they *Did Not Adhere*, cited poor time management or forgetfulness as factors (e.g., Appendix 9, Response 63), which are not positive study-related behaviors. Other students reported modifying their initial study plan based on their learning needs throughout the semester (e.g., Appendix 9, Response 89), which is indicative of metacognitive processing. There were no means to differentiate these potential causes of non-adherence, which is a limitation of our instrument. In the future, we hope to include additional prompts asking students to reflect on the success of their study plan and if and *how* they planned to modify it. In addition, we note that 25.1% of students reported a decrease in their motivation to study due to time-related factors (Fig. 10). These students often cited factors such as high course loads that resulted in procrastination (e.g., Appendix 9, Response 97). It may be that students who were unable to adhere to their study plan as a result of time-related factors experienced decreased motivation to study.

Exam-Wrappers have been shown to aid in the development of SRL strategies and contribute to students' academic success (7, 9, 38, 39, 58–60). Specifically, Exam-Wrappers can help students reflect on preparation methods and assess factors contributing to their performance on assessments (38, 40). In our study, student feedback was positive regarding the effectiveness of the Exam-Wrapper in the self-reflection process (e.g., Appendix 9, Response 14). The majority of respondents found the Exam-Wrapper to be effective in developing SRL skills across the entire spectrum of academic performance (Fig. 6 and 7). Moreover, students predicted their midterm exam grades effectively: 102 out of 180 respondents predicted their grades within 10 points of their actual midterm grades (in the range of ±10 points), suggesting that guided and timely reflection can promote metacognitive processing (Fig. 4B).

The Post-Course Survey is a reflection tool administered at the end of the course to assess factors such as motivation and metacognition through self-reporting and scaled questionnaires (61). Our Post-Course Survey solicited students to reflect on their learning journey and SRL strategies throughout the course and consider which study strategies they might employ in the future. Regardless of their academic performance in the course, students candidly reflected on their preparation for assessments and reported that the tools allowed them to identify areas for improvement (Fig. 6) and develop effective long-term study habits (Fig. 7). Moreover, students reported struggling with motivation but demonstrated aspirations to become better learners by shifting to more effective active learning strategies in the future. We can therefore conclude that by using instruments like the Exam-Wrapper, students can effectively reflect on their test preparation methods, study strategies, and long-term study habits, indicative of metacognitive processing.

### Students reported using the study strategy resources provided

Studies have shown that students are often unsure of how to devise a study strategy plan (3) and that exposure to study strategy resources can improve overall student learning (8, 30, 32). In our study, 82.9% of students reported using the resources provided in some capacity. Hence, the majority of students found the resources useful when creating their study plan for the semester (Fig. 9A). Students' comments corroborated our intentions to promote SRL by coupling exposure to these resources with the Pre-exam Planning Worksheet (e.g., Appendix 9, Response 78).

The two most utilized study strategies from the resources provided were *Recitation* (17.5%) and *Feedback* (10.5%) (Fig. 9). Both are metacognitive strategies that involve students monitoring their learning to evaluate whether new information is understood and integrated (62–64). Students preferentially selected these strategies over behavioral or motivational strategies (such as the *Environmental Design*, *Concentration*, and *Intention* strategies highlighted in the tipsheets, Appendix 1) to develop their study plans. Metacognitive strategies, such as active reviewing, may improve academic learning and achievement (21), whereas behavioral strategies, such as reading over notes, facilitate initial information acquisition and memorization without deeper understanding (64). Therefore, students may use behavioral strategies to first acquire the foundational knowledge needed, then shift focus to active learning strategies for deeper understanding as they concurrently hone their metacognitive skills. As behavior, motivation, and metacognition are all significant elements of SRL (Fig. 1) (1–3), it may be beneficial to support students in the future by suggesting that they combine and balance strategies from each category of our tipsheet resources.

While there is no significant difference in grade change between students who reported using the resources provided and those who did not (Fig. 9B), we acknowledge that there could have been additional factors influencing this result. For example, students may have been familiar with one or more of the study strategies highlighted in the resources provided prior to this course. Therefore, while students may not have consulted our resources, they may already possess a repertoire of effective study strategies. Understanding students' *prior* experiences and exposure to specific study strategies in our resources will be an important goal of a follow-up study.

## Conclusions

We achieved our overarching goal of supporting students with resources that promote SRL. The majority of our study's respondents reported using the resources provided to create and modify their study plans. Students were also able to reflect deeply on the effectiveness of their study strategies, indicating that they would modify their study plans in the future to center active reviewing over passive reviewing techniques. In addition, most students were also able to accurately predict their midterm grades following reflection on their perceived exam preparation and performance. These factors present evidence of strong metacognitive processing among students and highlight a motivation to improve study-related behaviors. Students also reported that the instruments helped identify areas of improvement and inspired the development of long-term study habits, illustrating positive student perceptions of the value of the reflection instruments used in our study. We conclude that supporting metacognitive processing and skill development through these instruments positively impacts study-related behaviors, motivation, and SRL. While Exam-Wrappers have been successfully implemented in several fields (28, 29, 38, 39, 58, 65), we encourage instructors across disciplines to supplement the Exam-Wrapper with the Pre-exam Planning Worksheet and the Post-Course Survey in foundation courses to further support SRL, reflection-informed metacognitive processing and skill development, and academic success of students.

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## ADDITIONAL FILES

The following material is available online.

### Supplemental Material

**Supplemental material (jmbe00103-S0001.pdf).** Additional information about the study's survey instruments and data analyses as well as the resources we developed as part of this project.

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