Rethinking Metacognitive Intervention:

A Scaffolded Exam Wrapper Strategy

by

Aaron M. Ridall

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APPROVED BY:

Advisor Date

Director of Graduate Studies Date

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Chapter One: Introduction

Anecdotal evidence from teachers at the secondary and postsecondary levels suggests that students aren't aware of what they don't know. This lack of metacognition, or thinking about thinking, presents a challenge for teachers since they cannot implement targeted supports unless they are aware of students' struggles. Metacognition can be divided into knowledge of cognition and regulation of cognition; knowledge of cognition refers to knowledge of oneself as a learner, knowledge about learning strategies, and knowledge about when and why to use specific strategies; regulation of cognition refers to planning, awareness of comprehension, and evaluation of applied learning strategies (Jayapraba, 2013). Some students may claim that they regularly demonstrate knowledge of cognition because they study in advance for a test and take notes in class. Many students, however, may claim that they do not have a high level of regulation of cognition and, therefore, lack self-regulation strategies associated with successful learners.

Metacognitive skills are not specifically taught in schools. With the implementation of strict education policies and high-stakes testing, teachers emphasize content over process skills—the skills that are transferrable and relevant to life outside of the classroom. This disparity is not surprising, given that teacher evaluations in the United States are often based on student performance on high-stakes tests. Therefore, teachers do not explicitly teach learning strategies in class yet they expect students to be cognizant of and internalize effective strategies. As students proceed through their education different habits of mind are required that reflect higher-ordered thinking and processing in Bloom's Taxonomy (Bloom, 1956). Students perceive that the only skills required at the secondary level are remembering and understanding while the same students believe that applying and analyzing skills are needed at the postsecondary level (Zhao, Wardeska, McGuire, & Cook, 2014). These higher-order skills are the foundations of metacognition; planning, monitoring, and evaluating are metacognitive skills associated with the learning cycle (Zepeda, Richey, Ronevich, & Nokes-Malach, 2015).

Recent work on metacognition suggests that teachers can implement metacognitive practices without sacrificing curricular time. An exam wrapper is a metacognitive tool that offers easy implementation and immediate feedback to students on their summative assessment achievement in a course. Designed in 2013 by Marsha Lovett, exam wrappers give students the opportunity to reflect on both exam performance and on the effectiveness of their exam preparation. When exam wrappers are utilized multiple times in a course, subsequent exam wrappers also give students the opportunity to reflect on the changes that they made to exam preparations between the previous and current exam. Other metacognitive inventories, such as the Metacognitive Activities Inventory (Cooper & Sandi-Urena, 2009) or exam calibration inventories (see de Bruin et al., 2017; Foster et al., 2017; Tullis, Finley, & Benjamin, 2013) offer efficient measures of metacognitive skillfulness and are widely used in the current literature.

Current trends in applications of metacognition in education support the use of self-regulation and self-reflection after receiving summative data (see Callender, Franco-Watkins, & Roberts, 2015; Zepeda et al., 2015; Zhao et al., 2014). Appropriate self-regulation and reflection requires that students are aware of their errors and can make meaningful adjustments to their practices (e.g. study strategies) to improve their summative assessment outcomes.

Significance

Current literature on the benefits of metacognition in secondary and postsecondary education present that improved metacognition leads to improved grades (Young & Fry, 2008) and improved awareness of self (Hartwig & Dunlosky, 2012). Although there is an abundance of evidence pertaining to the benefits of improved metacognition and the current literature presents measures for assessing metacognitive skillfulness of students (see De Bruin, Kok, Lobbestael, & de Grip, 2017; Gezer-Templeton, Mayhew, Korte, & Schmidt, 2017; Metzger, Smith, Brown, & Soneral, 2018), work that suggests courses of action to monitor metacognitive skillfulness and then develop individualized improvement plans is non-existent.

Educators understand the value of individualized, scaffolded support for students at the elementary and secondary levels but the value of this support seems to be downplayed at the postsecondary level. Potentially postsecondary educators believe that their students already have the tools to be successful at the college level although current literature suggests otherwise (see Zhao et al., 2014). Metacognition has been proven to be effective in reducing the performance gap between high- and low-achieving students (Callender, Franco-Watkins, & Roberts, 2015) and metacognition can also compensate for aptitude gaps (Cooper & Sandi-Urena, 2009).

These findings suggest that metacognitive instruction should formally exist in university curricula.

Exam wrappers have been utilized in postsecondary education to encourage students to look over their exams and reflect on why they received the grade that they did (Stephenson, Craig, Zingaro, Horton, Heap, & Huynh, 2017). However, evidence suggests that students often elect not to pick up their exams and those that do spend little time reviewing their performance (Gezer-Templeton et al., 2017; Stephenson et al., 2017). If instructors are able to present evidence of the value of reviewing exam performance, students are more likely to take initiative to improve their future performances (Winkelmes, 2013).

Exam wrappers, however, need further modifications to effectively improve students' performances on exams. Current exam wrappers help students identify areas for improvement in their exam preparations and also identify gaps between what the students perceived would be assessed on the exam versus what the exam actually assessed (see Gezer-Templeton et al., 2017; Metzger et al., 2018). Exam wrappers do not offer individualized feedback to students, nor do exam wrappers suggest courses of action for students to take in order to make meaningful adjustments to preparation techniques. Therefore, in their current state, exam wrappers rely heavily on the assumption that all students have strongly developed metacognitive skillfulness and can self-identify the best plan of action moving forward from one exam to the next. The goal of this work is to develop a series of science exam wrappers that utilize current research on metacognitive skillfulness and exam preparation techniques to facilitate concrete courses of action for users of exam wrappers and to facilitate metacognitive skillfulness through an assisted self-regulatory tool.

Chapter Two: Literature Review

Contemporary Trends in Science Education

Issues in Science Education

A continuing problem in the fields of physical science, technology, engineering, and math [STEM] is the underrepresentation of women. Comparatively, women are less likely than men to enter STEM fields and are more likely to drop out of STEM domains at decision-making milestones (Cundiff, Vescio, Loken, & Lo, 2013). It is suggested that a primary reason for the disparity between men and women in STEM domains is women are not interested in STEM and choose to pursue different career paths. Underlying women's disinterest in science are notions of gender stereotypes that persist in society, education, and the STEM fields and those stereotypes have been previously shown to impact women's underrepresentation in mathematics (Cundiff, et al., 2013). Stereotypes linking gender to achievement in domains influence women and men's interest in those domains. In mathematics, specifically, strong math-male associations predict great likelihood to major in this field, whilst these strong math-male associations predict less desire in women to pursue graduate education in quantitative fields (Cundiff, et al., 2013). According to stereotype threat theory and stereotype lift theory stronger science-male associations should predict weaker science identification among women and stronger science identification among men (Cundiff, et al., 2013).

Cundiff, et al. (2013) presents the findings that among women stronger gender-science stereotypes are associated with weaker science identification and, therefore, fewer women pursue STEM career domains. Stronger gender-science stereotypes among men were associated with stronger science identification and, therefore, more men pursue STEM career domains (Cundiff, et al., 2013). Gender-science stereotypes and science identity together attributed to 35% of the variance in intent to persist in science among women and 20% of the variance among men (Cundiff, et al., 2013). Based on prior findings Cundiff, et al. (2013) believed that gender-science stereotyping and gender identification would together influence science career aspirations. According to Cundiff and colleagues' work, however, the aforementioned influence was not quantified.

Although not as striking as the issue of the underrepresentation of women in STEM fields, individuals with deficiencies in social settings are marginalized by current practices in STEM education. In most classrooms, teachers leave, on average, less than one second of wait time after asking a question before speaking again (Ingram & Elliott, 2015) and this practice is biased against individuals with slow processing skills or social anxiety. However, extending wait time to at least three seconds has been shown to benefit student-teacher interactions in the classroom (Ingram & Elliott, 2015, p. 37) and it is further argued that wait time gives students more time to think and elicits more extensive, rich responses.

Ingram and Elliott suggest that as teachers move toward longer wait times and student responses become more explicative, this type of response becomes a norm in the classroom (2015). Teachers also have the means to structure the norms in their classroom by sanctioning self-selection and student-to-student interactions if they occur. Teachers also need to think critically about the appropriateness of extended wait time, since it is not a one size fits all methodology. The nature of the question should drive the use of extended wait time; a higher order question, requiring an explanation, inference, or support from data, is more successful given extended wait time, while a factual question requires shorter wait time. Although only noted briefly in the literature, the differential use of extended wait time can be adapted for various groupings of students. For example, students with more difficulty processing information may need more time and it would be helpful to conduct a turn-and-talk before selecting the next speaker. Jigsaw activities can also compliment a question so that students break down the question into parts and focus on the generation of a whole, complex answer rich in detail and evidence.

Assessments

A challenge that exists throughout education is the development of appropriate and effective measures of assessment. Although assessments are simply a snapshot of what a student knows at one point in time, education stakeholders misconstrue assessments as measures of instructor efficacy and as predictors of student achievement. Instructors do their best to predict exam performance by utilizing formative assessments. Formative assessments, or assessments for learning, involve processes of gathering evidence for use by students and teachers to inform where the students are in their learning and what next steps they should take to move forward. Grob, Holmeier, and Labudde (2017) summarize four ways in which formative assessment supports student learning: clarification of the intentions of learning assessment criteria, diagnosis of students' levels of achievement, provision of feedback, and fostering of self-regulated learning abilities. The goal of their work was to identify challenges associated with using the aforementioned formative assessment approaches in inquiry-based science education.

Challenges faced in using formative assessment methods were grouped into five categories: embedment of formative assessment activities, content and structure of the feedback, students' engagement with the feedback, relation between formative and summative assessment, and effort needed (Grob et al., 2017). Long-term challenges included planning for multiple types of assessment to keep it relevant, considering what feedback to give and when to guide peer-feedback sessions, as well as making formative assessment feedback as important as summative assessment feedback (Grob et al., 2017). Organizational challenges consisted of allotting appropriate time for feedback, determining when in the course of inquiry to provide feedback, as well as the planning for multiple stages of feedback, since self- and peer-assessment need practice to be successful.

Supportive measures could enable teachers to use formative assessment and feedback more effectively and more often. Supportive measures were presented in six categories, as identified by the teachers in the study: examples of good practice, time, assessment literacy, opportunities to reflect on assessment practices, exchange experiences, and clarification of the role of formative assessment (Grob et al., 2017).

At the postsecondary level, formative assessments are essentially nonexistent and assessments are often large-scale examinations. Freshmen science lectures, specifically, are largely assessed by multiple-choice examinations and assignments due to the exceptionally high number of students who declare their major in the sciences. Whether or not the entirety of an examination is multiple choice the use of multiple-choice assessments in large lectures solves as many problems as it creates; grading time is shortened, reliability of grading is guaranteed due to no variance in inter-rater reliability, results are more difficult to analyze due to random chance, and learning outcomes [LOs] are not strongly tied to the questions. However, Schultz

(2011) believes that the same question could be asked as a multiple-choice or short-answer question and that short-answer questions require a higher order problem solving approach. The use of non-multiple choice, randomized, online assignments for freshmen chemistry alleviates common problems with written multiple-choice or short-answer assignments, such as cheating, grader consistency/error, and grader time commitment.

Schultz modified course assessments by utilizing an online learning management system [LMS], where she randomly assigned assessment questions to each student from a pool of questions. Student responses to the change of assessment platform, from paper to online, support the use of online assessments to reduce cheating but students claim that online assessments do not accurately represent how grades will be determined for high-stakes summative assessments. The LMS does not award partial-credit even though instructors often award partial-credit on written assessments. Schultz notes that although an LMS does not solve all of the challenges associated with assessing students, it improves grade reliability, reduces grading errors, and reduces grader time commitment, since the LMS automatically grades the assignment.

Classroom Practices

One way in which teachers can assess learning in a risk-free environment is gamification. Gamification of learning, or the use of game design elements and mechanics in a learning context has been suggested as an up and coming trend in education. Gamification requires game mechanics/dynamics to cause interaction, competition, or collaboration in a domain that is anything other than a game. Currently over 50 percent of organizations use gamification to engage employees and corporations even use gamification to engage consumers, i.e. Frequent Flyer programs (gamification of enterprises) and Fitbit (gamification of health) (Fleischmann & Ariel, 2016). Gamification's success rests in the application of game attributes to other non-game scenarios including, but not limited to, motivation and goal orientation and personalization of content.

The success of gamification in industry has led to more research on the potential influence of gamification in other areas, most recently, education. Gamification has the potential to improve learning if it is well designed because gamification is inherently motivating, engaging, and allows for appropriate and seamless scaffolding of material to all ability levels, regardless of prior knowledge (Fleishmann & Ariel, 2016). While some may associate simulations with gamified learning content, computer simulations often lack the competitive nature of games, player control, and immediate feedback—three qualities that can assist and motivate students (Fleishmann & Ariel, 2016). In 2016, thirty students participated in learning activities associated with gamificiation: (1) lecture, (2) laboratory class, and (3) learning tool. Of the 30 students, 97% attended lectures and 100% attended the laboratory class and trialed the learning tool (Fleischmann & Ariel, 2016).

These students were surveyed at the end of the learning experience to gather feedback on the effectiveness of the three learning activities. Twenty-four students (83%) found lecture useful or very useful, twenty-two students (73%) found laboratory class useful or very useful, and twenty students (66%) found the learning tool useful or very useful (Fleischmann & Ariel, 2016, p. 150). Although the results signified that the majority of students believe all three learning methods to be useful, Fleischmann & Ariel (2016, p.150) present that five students (17%) claimed the learning tool was not useful—a category that was not selected for lectures nor for laboratory class.

Gamification can make the learning process more engaging once students have foundational knowledge in specific content areas. Most learning starts, however, with one of the most basic skills required for a successful educational experience—taking in information and reformatting it in a way that can be understood by others or by oneself at a later point in time. Many students practice reformatting information by taking notes, as is considered an expectation in college lectures (Cohen, Kim, Tan, & Winkelmes, 2013). However, current trends in post-secondary education undermine the importance of effective note taking. The availability of a professor’s PowerPoint slides prior to or following a lecture implies that students don’t need to take notes and therefore students aren’t summarizing information in their own words (Cohen et al., 2013, p. 95). Cohen and colleagues state that the process of note taking is as important—if not more important—than the product of note taking. Since students aren't taking notes during lectures, and those that are may not have been taught proper summarizing strategies, the process of note taking is hindered (Cohen et al., 2013).

Cohen et al. suggest two reasons why summarizing strategies have merit in post-secondary education. Lectures are not necessarily linear in nature and information presented in lessons can relate to prior lessons or even back to information in the current lesson; returning to one's notes and reorganizing information may help some student draw connections between ideas (Cohen et al., 2013, p. 95). Students also learn more during active learning sessions, in this case, reviewing notes, than during the sedentary note-taking process; therefore, reorganizing and summarizing one's notes allows a student to work with the material to identify themes and to fill in gaps (Cohen et al., 2013, p. 95). Cohen and colleagues suggest that more emphasis needs to be attributed to active classroom learning strategies and metacognition.

Science Process Skills

Science teaching in New York State prior to the establishment and adoption of the Next Generation Science Standards has been treated akin to Social Studies education—factual recall. Students have been assessed on what they know and how much they can memorize for tests such as the New York State 4th and 8th grade intermediate level science tests, as well as the Regents examinations. This style of assessing students and the inherent value traditional assessments place on rote memorization is not reflected in the science job field. Science process skills, the fundamental skills required to conduct scientific work, are not being addressed in science education, leading those with inherent science process skills to be the individuals that pursue science careers because of their success. Prayitno, Corebima, Susilo, Zubaidah, & Ramli (2017) postulate that closing the science process skills gap between students facilitates better holistic science education and supports all learners in the classroom.

Prayitno and colleagues found that inquiry-based learning and collaborative inquiry-based learning were more successful pedagogies than conventional learning or collaborative learning methods. Science process skills increased by 263% and 272% in students exposed to inquiry-based and collaborative inquiry-based learning, respectively, from the beginning of the study to the completion of the six-month period. Comparatively, collaborative inquiry-based learning improved science process skills 108% more than conventional learning did. Prayitno and colleagues' work also supports the heterogeneous grouping of peers to form collaborative inquiry groups. For collaborative learning to be successful, however, the authors claim that collaborative learning must be guaranteed and that inquiry-based learning must be guaranteed to be the learning process utilized in all classroom groups (Prayitno et al., 2017).

Science process skills need to be explicitly taught and practiced for students to excel in scientific research. However, the majority of undergraduate science work does not include content-specific research topics nor are the students in science programs required to conduct research as part of their coursework. McLaughlin, Favre, Weinstein, and Goedhart, in a 2017 study on the impact of an inquiry-based laboratory framework on students' laboratory skills and interest in content-specific research, present that 23% of undergraduate biology courses have no research component and 56% of courses spend less than a quarter of class time engaging in research (p. 84). Implementing undergraduate-level research experience is deemed a necessity in natural science courses, especially because of employer expectations in the science domains, and undergraduate research is positively linked to degree completion and academic success in biology (McLaughlin et al., 2017, p. 83). However, college faculty present that lack of time is a major barrier to develop research experiences at the undergraduate level (McLaughlin et al., 2017, p. 84).

McLaughlin and colleagues believe that developing an authentic research model for undergraduate professors can simplify the development and implementation of undergraduate research experience in biology laboratories (McLaughlin et al., 2017, p. 84). The four-step pedagogical framework that the study was based on is as follows: (1) learn essential experimental techniques, (2) design an experiment, (3) carry-out experiment, and (4) interpret data and communicate results. When implemented at a 2-year and at a 4-year college, students showed significant increases in their skills perception scores, demonstrating an increase in their science process skills. Students noted that they specifically gained critical thinking skills, improved scientific literacy, and developed research and data analysis skills that would be helpful in the future, regardless of if their future career was science-related (McLaughlin et al., 2017, p. 87).

A process skill that educators have been encouraged to integrate in their classrooms, especially at the elementary and secondary levels, is content-specific literacy. With the development and rollout of the Next Generation Science Standards (NGSS), reading standards are specifically laid out for science education starting in kindergarten. Science literacy encompasses these reading standards and can be best defined as “any practices which utilize reading, writing, listening, or speaking to create, organize, and communicate scientific information,” (Wright, Franks, Kuo, McTigue, & Serrano, 2016, p. 1280). However, with the various demands that stretch teachers’ time and the pressure that schools have placed on high-stakes tests, teachers feel that there is little room left for research and integration of new literacy standards (Wright, et al., 2016).

Literacy instruction is necessary for students to be successful in science programs and careers. Employers view writing skills as a determining hiring factor and science research requires literature review, communication, and publication skillsets, directly supported by science literacy. Landau Wright and colleagues reviewed 22 articles identified by searching for peer-reviewed literature that contained the key words science and literacy. Of the 22 articles, 87% made specific recommendations for reading and 54% for writing instruction in science class. Reading was further broken down by the studies into reading comprehension, a focus in 82% of the studies, and vocabulary development, 63% of the studies (Landau Wright, et al., 2015, p. 1282). Social constructionism was found to be the most frequently recommended literacy theory, both implicitly and explicitly, as suggested in 17 of the 22 articles. Reading motivation was found to be the least prevalent literacy strategy in the literature, used in only 18% of the articles. It was also incredibly common that multiple theories were presented in a single article; out of the 22 studies analyzed, 16 referenced two theories, rather than just one.

Rarely do elementary and secondary education students read complex scientific literature, such as published lab reports, which creates a gap between the science skillset required of a high school student and the science skillset required of a college student. Improving scientific literacy at the postsecondary level, however, is a challenging accomplishment since most university students do not major in a science domain (Rutledge & Lampley, 2017, p. 20). The development of scientific literacy and other science process skills for the majority of college students, therefore, has to be embedded into general education science courses, also known as sciences for non-majors. In a 2017 study on engaging non-majors in science, Rutledge & Lampley present findings that many students lack an appreciation of the mission of a general education program, and therefore may view non-majors' courses as irrelevant. Students also tend to perceive that general education courses focus on lower-order thinking skills and the students are potentially not prepared for the rigor that the course may entail (Rutledge & Lampley, 2017, p. 20).

The purpose of Rutledge and Lampley's work was to reorganize non-majors' biology courses, using current issues in biology and society to frame the curricula. The reorganization of the courses also revitalized learning styles, from passive lectures to active learning models in order to promote student engagement and critical thinking skills (Rutledge & Lampley, 2017, p. 21). Overall test data show that students entered the non-majors' biology course with a moderately high (3.81 on a 5-point Likert scale) perceived understanding of the role of general education and left the course with a significantly higher understanding (Rutledge & Lampley, 2017, p. 23). Students also equivalently rated the goals of the college general education program and their majors by the end of the non-majors' biology course (Rutledge & Lampley, 2017, p. 24). Students, however, did not change their opinions on the view that general education courses are a vital part of their education by the end of the study. Students presented only a mild to moderately high degree of agreement with the importance of general education courses (Rutledge & Lampley, 2017, p. 24).

Effective Pedagogies in Science Education

In order to produce classroom environments conducive to the facilitation of science process skills, teachers are moving toward nontraditional teaching methods such as problem-based learning, flipped classrooms, and modeling. Problem-based learning [PBL] is a learning style that presents problems occurring in students' lives that stimulate learning (Mundilarto & Ismoyo, 2017). PBL seeks to address comprehension to the fullest capacity by rethinking what it means to teach content. Rather than traditional lecture teaching, PBL is developed and designed to help students build knowledge and to apply knowledge in effective problem-solving scenarios. The PBL method is student-centered and, like other active learning styles, requires students to actively seek information with teacher guidance, thereby building process skills.

Mundilarto & Ismoyo hypothesized in a 2017 study that problem-based learning could effectively improve student learning outcomes and critical thinking skills. Students who experienced problem-based learning showed a greater average gain in learning achievement than students who experienced demonstration-based learning. Applying knowledge and analyzing information were the two cognitive levels that showed the largest gain from pre- to posttest results. Students in the PBL cohort also showed more growth in critical thinking skills than their counterparts, suggesting that

PBL effectively improves cognition but also critical thinking skills that are expected and built upon in the natural sciences (Mundilarto & Ismoyo, 2017).

Problem-based learning can effectively enable students to solve situations that are tangible and relevant. Chemistry teachers, however, face a challenge in their careers that cannot be said about teachers in the other science disciplines; chemistry educators have the unique challenge of explaining abstract processes and submicroscopic occurrences to students and to make these processes relevant, a challenge for which PBL is not an effective pedagogy. One way in which chemistry teachers are able to engage students in learning about abstract processes is through the use of models. Modeling, which Maia and Justi (2009) describe as "…the dynamic and continuous process of creating, testing, and communicating models," (p. 603) enables students to visualize processes that would otherwise remain abstruse. Modeling in science contexts enables students to expand their scientific knowledge beyond the memorization of facts and equations. Guided inquiry learning and problem-based learning draw on models to generate student questions, concretize ideas, and to draw conclusions about naturally occurring phenomena.

Modeling as further described by Maia and Justi (2009) requires that students explain scientific phenomena, define and revise problems, and search for data. Therefore, modeling acts as a platform for students to engage in scientific process skills that move beyond traditional classroom expectations and into higher levels of Bloom's taxonomy. Maia and Justi (2009) present that modeling has the potential to not only strengthen student understanding of abstract processes but in doing so also address common student misconceptions about higher level chemistry concepts. In this study on the impact of modeling-based teaching on chemical equilibrium, Maia and Justi developed a scaffolded modeling system to guide students through the process of building, testing, and reevaluating models.

A case study of one of the groups within the classroom was presented as evidence for Maia and Justi's work. The case study found that in the initial activities, the students were able to build successful models that showed the broad concepts of reaction systems, but not the nuances associated with the underlying theories. However, students within the first two activities were able to generate discourse, with teacher guidance, about the reaction systems and evaluate previously presented ideas. This process can be referred to as rough draft thinking—the idea that a discourse can be reevaluated and built upon as new information is learned. Maia & Justi describe that student understanding of equilibrium was largely impacted by intragroup discourse; ideas presented by one group were built upon and amended by another to reach conclusions that students perceived to be true (Maia & Justi, 2009, p. 617). The anecdotal assessment evidence provided by Maia and Justi supports that student groups were able to successfully generate coherent models for chemical equilibrium (2009, p. 624).

Problem-based learning and modeling are effective pedagogies for elementary and secondary education, where attendance is compulsory. A decline in classroom attendance on college campuses, though, highlights the need for more engaging curricula since attendance is positively correlated to academic achievement (Smallhorn, 2017). A classroom model that has gained traction for fostering engagement in undergraduate education is the flipped classroom. The flipped classroom model places emphasis on student pre-class work so that face-to-face contact time is focused on problem solving, peer collaboration, and application of the material (Smallhorn, 2017). Flipped classrooms engage students with the content in a meaningful way and educators can address misconceptions in a timely manner. Smallhorn (2017) presents that although there is clear evidence of improved student engagement in the flipped classroom, it is unclear if the flipped classroom model leads to improved academic performance.

Student attendance data prior to the implementation of the flipped classroom showed 10-15% of enrolled students present during weekly lectures (Smallhorn, 2017, p. 48). After the transition to the flipped classroom model, average weekly attendance was 61% of enrolled students (Smallhorn, 2017, p. 48). Students who attended more frequently, and therefore were more engaged, subsequently earned higher final grades than their counterparts. Smallhorn also categorized students into groups based on level of engagement: highly engaged (nine or more classes attended), moderately engaged (six to eight classes), and poorly engaged (five or less classes). There was a correlation between level of engagement and academic achievement and 88% of students who achieved above an 85 average were highly engaged (Smallhorn, 2017, p. 49). Student assignment submission rates also increased after the transition to the flipped classroom model, which shows more support for the hypothesis that the flipped classroom model leads to improved classroom engagement. An analysis of final exam performance after the transition to the flipped classroom model showed no improvement over prior final exam performance scores. This suggests that the flipped classroom model does not support academic achievement (Smallhorn, 2017, p. 50).

Metacognition

A challenge facing many first-year college students is making an adjustment to time management and study habits (Korte, Reitz, & Schmidt, 2016). Students at the postsecondary level believe that their high school habits will be effective at the college level, which is often not the case. Secondary education curricula emphasize rote memorization tasks, rather than the critical thinking and process skills required at the postsecondary level (Korte et al., 2016, p. 23). Improving critical thinking requires a different set of study and preparation techniques than the flashcard or note review techniques used in secondary schools; metacognitive tasks are linked to improved critical thinking and so strategies that improve metacognition will lead to improved critical thinking. Korte and colleagues refer to two major metacognitive resources to use at the postsecondary level: Bloom's Taxonomy of Educational Objectives and the Louisiana State University (LSU) Study Cycle (p. 24).

Korte et al. sought to evaluate the impact of student-centered learning practices at the postsecondary level. The student-centered practices consisted of required assignments and optional study tools as well as supplemental resources for learning. To evaluate the impact of the learning resources, Korte et al. administered five exams and two surveys—one at the midterm and the other at the end of the course. The surveys included quantitative questions, utilizing Likert scales and dichotomous responses, and qualitative questions, utilizing open-ended responses. Students rated quizzes as *excellent* or *very good* for enhancing their learning of course material, which is surprising given that quizzes have a reputation of being not well received by students (Korte et al., 2016, p. 29). Supplemental learning resources, however, were perceived to be the least valuable resources to help students perform better in the course.

Results from the summative exams show that overall scores increased by an average of 2.6% the semester of the study, when compared to the previous 5 semesters (Korte et al., 2016, p. 31). The final exam score for the study semester was 0.24% lower than the previous semesters, however. The final exam results should not necessarily serve as the sole support for curricular or pedagogical changes. The authors report that students who have earned an A- in the course prior to the final exam are not required to take the final and in the study semester 49.5% of students did not take the exam (Korte et al., 2016, p. 31).

In an attempt to bridge the gap between the skills required in secondary and postsecondary education, educators are increasingly investigating metacognitive instruction. Metacognition, or thinking about thinking, is broken down in current literature into three skills: planning, monitoring, and evaluating (Zepeda, Richey, Ronevich, & Nokes-Malach, 2015). The metacognitive skills presented can be associated with stages in the learning process, forethought phase—planning, performance phase—monitoring, and self-reflection phase—evaluating (Zepeda et al., 2015, p. 955). Planning, monitoring, and evaluating also generate measurable categories and themes on which to assess students' use of metacognitive strategies. In the planning category, students who learn about metacognition might be more likely to adopt mastery-approach goals, rather than normalized goals (Zepeda et al., 2015, p. 955). In the monitoring category, students who learn about metacognition might be more aware of their own control of learning. And in the evaluating category, students who learn about metacognition might be better at identifying learning behaviors that led to a particular outcome.

Students' conceptual knowledge, perceptions of metacognition, learning strategies, goal orientations, theories of intelligence, and need for cognition were assessed by Zepeda and colleagues utilizing written tests and surveys, one for each category. Results from analyses of problem solving and packet quizzes show that the students who received direct instruction on metacognitive strategies acquired declarative knowledge, or knowledge about descriptive information, of the metacognitive skills presented in the intervention (Zepeda et al., 2015, p. 963). The results from the various self-reports utilized in the study present that students who received the intervention had higher self-efficacy and task value than their counterparts. Metacognition instruction also led to an increased emphasis placed on mastery-approach goals, rather than normative goals, and on a growth mindset approach (Zepeda et al., 2015, p. 965). There was, however, no effect on students' need for cognition, performance-approach goals, or performance-avoidance goals. Students in the experimental group also demonstrated less of a confidence bias when choosing correct answers, a sign of a step towards self-reflection.

Zepeda and colleagues' work supports direct instruction of metacognition in secondary education and could possibly have implications in elementary and post-secondary education as well. Although not all of the areas that Zepeda et al. assessed benefitted from direct instruction of metacognition, metacognition increased students' endorsements of the majority of the measures. Improvement in knowledge transfer, a major focus of the study, was seen through the results of the problem solving and packet quizzes, which has meaningful implications about the structure of class time, especially at the secondary level. Zepeda et al. present that students that received the metacognition intervention spent more of their instructional time on metacognitive learning rather than on content learning but outperformed their peers on content-based questions, suggesting that the teaching of metacognitive strategies can reduce the need for repeated practice of content-based material.

Zepeda and colleagues also present that metacognition instruction improves student motivation for learning. A key facet of creating welcoming and effective classrooms is bolstering student motivation, so this evidence may support a modified educational framework that postpones content-based instruction for metacognitive instruction. The long-term efficacy of metacognition instruction, as presented in Zepeda et al. (2015), suggests early introduction of metacognitive strategies in schools. Metacognitive strategies can be scaffolded for use in elementary schools, where students can be instructed on the foundational aspects of metacognition, such as performance indicators. The use of metacognitive strategies in secondary schools is presented in Zepeda et al. (2015), and the utilization of metacognition can even be scaffolded at the post-secondary level, where students can be instructed in self-reflective measures of class preparation, performance, and engagement.

The importance of metacognitive skillfulness at the postsecondary level contributes to an emerging theme in science education—a transition to process knowledge, or knowledge of how to perform tasks, rather than traditional declarative knowledge, or knowledge of facts. Declarative knowledge rarely has applications beyond the classroom or on written examinations. Process knowledge, however, is representative of what employers look for: an individual's ability to take information and apply it to novel and unexpected situations. Critical thinking is directly related to process knowledge; critical thinking, according to Magno (2010), occurs when individuals utilize information or skills to increase the probability of a desired event.

Metacognition is an underlying requirement for higher level critical thinking skills. In order to think critically, Magno (2010) posits that an individual must monitor his thinking, evaluate whether progress is being made toward the goal, and make appropriate planning decisions. Magno's work suggests a positive correlation between metacognition and critical thinking and all factors of metacognition were significant. Increases in scores on factors of critical thinking were related to increased use of metacognition factors (Magno, 2010, p. 145). Regulation of cognition skills were more significant than knowledge of cognition skills, however both are significantly related to critical thinking skills. Metacognition also significantly increased the variance of critical thinking (Magno, 2010, p. 146).

Magno's work support further supports introducing metacognitive instruction into the general education curriculum. As universities are emphasizing the production of culturally and socially literate students, critical thinking supports the development of individuals who make informed decisions. Furthermore, the relationship between metacognition and critical thinking, as presented by Magno (2010), suggests the need for a restructured secondary and post-secondary science curriculum. Although the importance of critical thinking cannot be overlooked in all content-areas, it is by far most evident in the natural sciences and should, therefore, be addressed through best practices and with an understanding of current literature.

Magno also suggests that the processes of metacognition and critical thinking are carried out by a subset of students he calls "expert types of learners," (p. 151). Although not all students are expert learners, teachers can enable students to utilize success-facilitating skills. Expert types of learners are better able to analyze information with a critical lens and make judgments backed by logic, reason, and supporting evidence (Magno, 2010). Individuals who think critically are not only successful academically but they are informed consumers of products and information.

Metacognition and Academic Performance

Metacognition not only improves critical thinking skills but metacognition, according to Cooper and Sandi-Urena (2009), is key to deeper, transferable learning and is needed to achieve content mastery. The underlying challenge with any work in metacognition is in obtaining quantitative data since metacognition is a relatively innate skill. Metacognition, though, can be broken down into two components, knowledge of cognition and regulation of cognition, which may be useful in quantifying metacognitive skills. Regulation of cognition, specifically, refers to the actions individuals do to control their own cognition (Cooper & Sandi-Urena, 2009, p. 240) and can be broken down into planning, monitoring, and evaluating. These regulatory processes not only guide metacognition but also problem solving and therefore improvements in regulation of cognition should improve problem solving efficiency.

Cooper and Sandi-Urena present that children with higher metacognitive levels outperform those with lower metacognitive ability and that improving metacognition may compensate for aptitude gaps (p. 240). The Metacognitive Activities Inventory (MCAI) was administered over three consecutive semesters to chemistry students at a research university. Participants in the main study were students enrolled in laboratory sections of general chemistry 1 and participants in the subsequent replication study were students enrolled in their first year of graduate school. A total of 537 participants completed both the pretest and posttest MCAI (Cooper & Sandi-Urena, 2009). Analysis of the pretest and posttest results present that the mean value for the graduate students was significantly higher than that for the undergraduate students. A comparison of student achievement and MCAI results found that there is a positive correlation between letter grade and MCAI mean score. Replication of the test administration and the subsequent data analysis support that the MCAI is a reliable metacognitive assessment tool (Cooper & Sandi-Urena, 2009).

Metacognitive knowledge has been assessed using the Metacognitive Awareness Inventory (MAI)—a precursor to Cooper and Sandi-Urena's MCAI—since its development in 1994 (Young & Fry, 2008). The inventory is a 52-question true-false assessment that consists of questions pertaining to metacognitive knowledge and metacognitive regulation. The MAI has been utilized so often since its development because it is a quick and effective tool with which to assess metacognitive awareness (Young & Fry, 2008, p. 4). However, the MAI itself has not been the source of many studies, nor has literature been generated on the relationship between MAI performance and academic achievement at the secondary or postsecondary levels. Young and Fry conducted their work to analyze the relationship between the MAI and end of course grades, cumulative GPA, and individual exams within a college course. The researchers also wanted to determine if the MAI scores could distinguish between undergraduate and graduate students (Young & Fry, 2008, p. 5).

The mean MAI score for the respondents was 206.85, with a 68.69 and 138.16 score for knowledge of cognition and regulation of cognition, respectively. There was a significant correlation between the two factors, as well (Young & Fry, 2008, p. 7). There was also a correlation between the MAI total score and the end of course grades, as well as between the MAI total score and GPA. This suggests that metacognitive awareness is related to academic achievement. Correlations between individual test scores and the MAI were inconclusive; there were no significant correlations between test 1 scores and scores on the MAI and test 2 scores and scores on the MAI but there was a correlation between test 3 scores and scores on the MAI (Young & Fry, 2008, p. 7). When analyzing the undergraduate and graduate students' MAI scores, there was only a significant difference between the scores with regard to the regulation of cognition factor.

The finding that the MAI is tied to broad measures of academic performance, such as GPA, has important implications for university professors. Professors can use the MAI to assess general aptitude of their students and flag students who obtain low scores. Item analyses for low scoring students can allow professors the ability to set up personalized, scaffolded plans to best support the students. The MAI is also a quick assessment to administer that has been proven to be effective through face-to-face and online course platforms (Young & Fry, 2008), suggesting its suitability at the undergraduate and graduate levels. The MAI is limited in its applications, however. As a tool it can only identify areas of deficiency in students' metacognitive awareness; the MAI cannot improve students' metacognitive awareness, nor can it suggest a plan for the instructor who is utilizing the tool. This will be discussed further in the implications section of this work.

If metacognition is directly related to student achievement, then students should be able to accurately predict their exam performance before receiving feedback. When students predict summative exam performance, however, they are often highly inaccurate and most students tend to be overconfident in their performance (Foster, Was, Dunlosky, & Isaacson, 2016). Foster and colleagues present that prior research on student exam predictions suggests that judgment accuracy does not increase over time (p. 2). However, Foster et al. (2016) claim that the literature on student exam predictions is riddled with classroom variables that were not addressed in the research, like metacognitive training or class effect, for example. Foster and colleagues' work attempts to determine: 1) if prediction accuracy increases as students take more exams, 2) if students rely on memory for past exam performance (MPE) when predicting future exam performance, and 3) if students should use MPE to make future exam predictions (2016, p. 5).

Foster and colleagues found that on average, students were overconfident in their exam performance (p. 6). Students overestimated their performance by 6.90% on average and their predictions became less accurate as the semester progressed (Foster et al., 2016, p. 7). Students also inaccurately predicted their performance based on prior exam scores. Students predicted higher upcoming exam scores by 6.49 points relative to their prior exam scores (Foster et al., 2016, p. 8), suggesting that the students did not increase or decrease their reliance on MPE throughout the course.

Foster and colleagues also found that the average difference between adjacent exams was very close to zero, suggesting that MPE is a good diagnostic tool for current exam performance predictions. However, students did not appear to use the score from a prior exam as a factor when making a new prediction; students' current exam predictions were marginally adjusted based on prior exam scores (Foster et al., 2016, p. 9).

Foster and colleagues' findings further contribute to literature on students' perceptions of academic achievement performance at the college level. This work is the first of its kind to assess the validity of student performance predictions over an entire semester, utilizing more than ten exams. Foster and colleagues' work further supports the finding that students are unable to accurately predict their exam performance and are also unable to accurately improve their exam prediction calibration. Failure to improve exam performance predictions suggests the need for initiatives that improve student metacognition to include exam preparation strategies. Foster et al. (2016) did not offer students mechanisms by which to make improvements to their exam performance predictions. Therefore, it is unknown as to whether students, with facilitation, can make the necessary changes to improve exam calibration.

Foster and colleagues' work begs the question: If students cannot improve exam performance predictions throughout a semester, how should instructors facilitate strategies to make improvements in exam calibration?

Self-Regulation

Self-judgment, a method of metacognition, in education can be facilitated through the use of surveys prior to or following a graded assessment. Self-judgment prior to an assessment is less effective than self-judgment following an exam because students are more knowledgeable about the difficulty of an exam after the fact and can use this information to inform their judgments (Callender et al., 2015, p. 218). Callender and colleagues studied the impact of direct instruction of metacognition on student performance, where student performance was defined as both academic performance and judgment perceptions. Callender and colleagues believed that with metacognition training, incentives, and feedback, student performance and judgments would change differentially based on ability level (2015, p. 219).

The results of S_1 show that there was a disparity between judgment-performance calibrations for high achieving and low achieving students. Students that earned A's and B's on exam 1 predicted that they would score worse than they did, while students that earned C's, D's, and F's believed that they would do much better than they actually performed. However, there was no significant difference between judgment and performance on exam 2 (Callender et al., 2015, p. 225), supporting that students improve calibration between the two exams and further supporting that direct metacognition instruction improves student judgment-performance calibration. Judgment changes were most notable in the D/F group and the group also made the most notable performance improvements overall (Callender et al., 2015, p. 226).

Students in the D/F group, however, were less likely than the high performing students to make changes in both judgment and performance.

The results of S_2 show that the students in the Feedback group changed both their judgments and performances from exam 1 to exam 2, whereas students in the No Feedback group made no significant changes to their judgments or performances. In looking at the D/F group specifically, Callender and colleagues found that test performance improvement was significantly greater in the Feedback group versus their counterparts (Callendar et al., 2015, p. 229). Furthermore, changes in performance predicted judgment changes but only for the Feedback group.

Callender and colleagues' work implies that metacognitive instruction may help reduce students' judgment-performance gap, but more importantly reduce the overall performance gap between high achieving and low achieving students. An underlying implication in Callender et al. (2015) is that although metacognitive instruction differentially benefits students based on achievement level, metacognitive instruction does benefit all students, regardless of achievement level. Therefore, investing time in the practice of metacognition is worthwhile to all students because metacognitive practices can improve judgment-performance calibrations and improve academic performance. Callender and colleagues also suggest that metacognitive practices with instructor feedback further develop student metacognitive ability. Feedback was most significant among the lowest achievement cohort, which is the cohort that is often targeted for academic interventions. The measured value of metacognitive strategies among the D/F cohort suggests that direct metacognitive instruction should be utilized as an intervention strategy, if not utilized for all students already.

The Dunning-Kruger effect describes the tendency of poor performing students to exhibit overconfidence in their summative exam performance. In contrast, high performing students tend to exhibit accurate predictions of exam performance or slightly underconfident predictions (De Bruin, Kok, Lobbestael, & de Grip, 2017). De Bruin et al., however, present that students' predictions trend around 70-80%, which is close to the actual scores of high performers but is significantly different to the actual scores of low performers (p. 22). Inaccurate performance calibrations by low performing students is a dual-faceted issue. These students have insufficient knowledge of the content and also have less metacognitive skillfulness, which means that low performing students are unaware of the content and unaware of their knowledge levels (De Bruin et al., 2017, p. 23).

If teachers seek to improve students' performance calibrations sufficient practice, persistence, and resources are required. Teachers need to provide self-assessment and self-reflection scaffolding opportunities within a course, as opposed to assuming that students will develop the skills on their own. De Bruin and colleagues' work not only sought to investigate how students' performance monitoring accuracy changed over the course of a semester but also how an intervention would affect performance calibration and exam scores. The researchers also sought to determine the impact of personality traits on monitoring accuracy (De Bruin et al., 2017, p. 26).

De Bruin and colleagues determined that students' performance calibrations improved with time. Although the differences between predictions and exam scores decreased within the set time frame, there was still significant evidence of overconfidence and underconfidence. The authors found that the highest quartile remained underconfident in their predictions while the two lowest quartiles were overconfident in their predictions (p. 32). Absolute accuracy—the difference in actual exam score and predicted exam score—at the beginning of the course predicted absolute accuracy at the end of the course. Students who received the monitoring and regulation strategy intervention were slightly more accurate in their predictions than those who did not receive the strategy (De Bruin et al., 2017, p. 32). Students in the control group were overconfident, while students who received only the monitoring exercise were underconfident in their predictions. However, absolute accuracy of the three experimental groups was not significantly different than zero, so no significant amount of overconfidence was observed in any of the experimental groups prior to the exam (De Bruin et al., 2017, p. 33).

De Bruin and colleagues also determined that the monitoring and regulation strategy resulted in increased exam scores for students, but the monitoring exercise did not. Surprisingly, the combination of the two strategies was not as effective at increasing exam scores as the monitoring and regulation strategy alone, as evident in the mean exam scores of 6.42 and 6.78, respectively (De Bruin et al., 2017, p. 33). In terms of personality traits, the authors found that students who exhibit grandiose narcissism showed more overestimation of their exam scores, whereas students who exhibit vulnerable narcissism showed less overestimation of their exam scores. Optimism was not significantly related to exam performance calibration (De Bruin et al., 2017, p. 34).

De Bruin and colleagues' work strongly suggests that student performance calibration can be improved by interventions. Although only two time points were used for data collection, the monitoring and regulation strategy caused significant improvement in exam scores and student performance calibrations. The combination of exam score and calibration improvements caused by one unobtrusive intervention suggests that teachers do not need to explicitly instruct in metacognition to improve student performance.

One method of improving self-regulation is the use of metacognitive strategies embedded into lessons (Peters & Kitsantas, 2010, p. 383). Observation, emulation, self-control, and self-regulation are four processes that can be utilized to develop metacognitive skills. Peters and Kitsantas' study utilized embedded metacognitive prompts on the nature of science (EMPNOS) in inquiry-based modules to show differences in content knowledge, knowledge of the nature of science, metacognition, and self-regulatory efficacy between an experimental and control group.

Pretest differences between the experimental and control groups revealed no significant differences for any of the five measures. This was expected because students are heterogeneously grouped in science classes, so no significant difference should persist due to differences in ability. Analysis of the posttest results found significant differences between the experimental group and the control group in content knowledge and knowledge about the nature of science, with the experimental group outperforming the control group in both measures (Peters & Kitsantas, 2010, p. 389). The experimental group also demonstrated a large gain in self-efficacy from pre- to posttest. Metacognitive orientation of the classroom and metacognition of the nature of science, however, were not significantly different between the two groups. Positive correlations among all five variables in the study were discovered.

Peters & Kitsantas support that embedded metacognitive prompts based on the nature of science can increase student content knowledge and nature of science knowledge. Explicit exposure to scientific epistemologies helps students view science as a way of knowing, rather than view science as a content area or course of study. Teachers can utilize EMPNOS in pre-existing lesson plans to scaffold understanding of the nature of science and to improve content knowledge across all student cohorts. Peters & Kitsantas, however, do not present information about how the intervention impacted achievement level cohorts, specifically; information is not available in the current study on whether growth among high achieving students was comparable to growth among low achieving students. Work should be done to determine if embedding prompts into a lesson effectively benefits all students or it works better with certain cohorts of students.

Exam Wrappers

Although Peters and Kitsantas support metacognitive tools embedded into lessons, a plethora of literature exists on improving metacognition without sacrificing significant amounts of class time. One possible method of facilitating self-regulation and study skills at the college level is the use of exam wrappers, as presented by Gezer-Templeton, Mayhew, Korte, & Schmidt (2017). Exam wrappers are short, self-reflective writing tasks that ask students to review their exam preparation methods in relation to their exam performance. One of the benefits of exam wrappers is that instructors can modify the wrappers to address individual course questions. Teachers and professors, however, note the challenges associated with utilizing exam feedback to support student growth. Gezer-Templeton et al. note that some students receive exams and exam feedback only to place the exams into their binders or trash and not review their own performance. A more effective exam feedback cycle involves the inclusion of self-assessment, goal setting and implementation, and then exam preparation (Gezer-Templeton et al., 2017, p. 29) and this feedback cycle is the foundation of exam wrappers.

Students' predicted exam grades were compared with their actual exam grades to determine how accurately students perceived their exam performance. Students with a higher average exam grade tended to underestimate their performance, while students with a lower average exam grade tended to overestimate their performance for all three exams, which is in accordance with the Dunning-Kruger effect (Gezer-Templeton et al., 2017, p. 30). The current work also found that there was no significant correlation between the number of study strategies used by a student in exam preparation and their exam grade. Moreover, students who used more effective study strategies did not show improved grades compared to students who only reviewed class notes or attended review sessions (Gezer-Templeton et al., 2017, p. 31).

An important result from Gezer-Templeton and colleagues' work is that the number of students who started reviewing earlier increased after the first exam. This shows promise that students were applying study strategies suggested by the researchers and following suit, starting in advance was one of the most frequently self-identified study goals by students (Gezer-Templeton et al., 2017, p. 32). Students who improved their exam scores to a B throughout the study most regularly utilized study behaviors that were included in the analysis. Gezer-Templeton and colleagues' work also suggests that exam wrappers can be utilized as beneficial self-reflection tools. As noted in the study, exam wrappers are easy to implement since they aren't time consuming, instructors can modify the exam wrappers, and exam wrappers can be utilized for subsequent exam (p. 29). Overall student perception of the exam wrappers was that the tools were useful to their learning, which suggests that exam wrappers can be used effectively.

Soicher and Gurung, in a 2017 study on the impact of exam wrappers on performance and metacognition, present that the most successful students at the college level are the ones who can adapt their own learning goals to the different demands of the courses (p. 65). Unfortunately, students often lack the ability to modify their learning approaches and students are also more likely to use preferred study and classroom practices over recommended practices (Soicher & Gurung, 2017, p. 65). Soicher and Gurung's work ultimately stemmed from two main student metacognition themes identified in the current literature: 1) students perform better on comprehension tasks if they are explicitly taught self-monitoring techniques and if the students also utilize the techniques, and 2) exam wrappers—structured post hoc exam performance reflection tools—have been applied effectively to improve course performance. Soicher and Gurung's work builds upon the current literature by determining the impact of exam wrappers on student performance and metacognition in a single course, with both an experimental and control group.

Soicher and Gurung's data analyses suggest that exam wrappers did not significantly impact any of the mid-semester exam scores, nor did exam wrappers significantly affect final grades (p. 67). Students' MAI scores also did not significantly impact their final course grades. Soicher and Gurung conducted additional analyses to determine if students needed to complete all exam wrappers to make improvements in the course. Results showed no significant difference in any of the exam scores or final grades between students in the experimental group versus the placebo group (Soicher & Gurung, 2017, p. 68). There was also no significant difference in metacognitive growth between the exam wrapper and placebo groups. However, MAI scores were higher at the end of the semester than at the beginning when Soicher and Gurung analyzed all groups collectively. The initial MAI scores also were related to final grades.

Students learn best when the class material is meaningful and relevant, and when the value of the learning is apparent. However, since Soicher and Gurung's work is novel, the value of exam wrappers can only be presented superficially to students. The potential student resistance to utilizing exam wrappers, as noted by the almost 67% of participants that did not complete all three exam wrappers (Soicher & Gurung, 2017, p. 68), therefore, may have impacted the author's findings.

The authors report that their findings about the negligible impact of exam wrappers on student performance across a single course are consistent with past research (Soicher & Gurung, 2017, p. 69). Although the impact on a single course is negligible, the authors suggest that exam wrappers might be more beneficial if entire departments use the tool or if the whole school utilizes exam wrappers. This work also supports current research suggesting that metacognitive strategies are effective only if explicitly taught and utilized consistently. Since exam wrappers are only a reflective tool and therefore require the users to determine next steps in the process, exam wrappers may not be filling the self-monitoring void that they were designed to satisfy. Work should be done to evaluate the efficacy of modifying exam wrappers to include guidelines to support students' future exam preparation.

The discrepancies between students' perceptions and the actual truths are a source of concern for stakeholders in post-secondary education. Traditional undergraduate courses focus on subject matter and content and leave out the importance of practicing metacognitive skills (Metzger, Smith, Brown, & Soneral et al., 2018, p. 89). Metzger et al. (2018) created a metacognitive tool in the hopes that metacognition could become a learning process in undergraduate institutions. "The Student Metacognition, Affect, and Study Habits (SMASH) inventory was designed as a repeatable reflection to be incorporated within the summative assessment structure of a course," (Metzger et al., 2018, p. 88). The SMASH inventory is a 25 item, context specific instrument that is delivered immediately following a summative assessment. The SMASH inventory was coupled with the Writing, Reflection, and Planning (WRaP) exam wrapper and this combination of metacognitive tools attempts to encourage students to reflect on their exam preparation strategies and exam performances.

Analysis of the data from the SMASH inventories and WRaP exam wrappers support that the thematic category 'systematic study habits,' was linked to the greatest proportion of variability in student assessment results (Metzger et al., 2018, p. 92, 95). However, student responses in the factor Perceived Difficulty, spanning the SMASH categories 'reflecting thinking' and 'meta-emotional', were the most predictive of student performance (Metzger et al., 2018, p. 95). The findings from Metzger et al. (2018) suggest a new method of office hours' consultations for higher education stakeholders. The use of the SMASH and WRaP inventories, as noted, generates unfeigned responses to students' attitude and study behaviors. In turn, the information gathered from the inventories can allow professors to have meaningful, targeted conversations with students about preparation for future class sessions and assessments. The responses generated from the SMASH and WRaP inventories can also be used to help students understand the possible source(s) of their missteps in course preparation. Metzger et al. (2018) presents that students may be intimidated by opening up to a professor about exam preparations (p. 96), and this can further skew students' views on what appropriate preparation for coursework entails.

Study Strategies

Exam wrapper strategies are effective at enabling students to identify their preparation deficiencies but exam wrappers do not offer next steps for students to take in order to improve their practices. Zhao, Wardesk, McGuire, & Cook, in a 2014 paper on the impact of metacognition in college science present that not all students possess the required habits of mind to be successful in college. Besides the cognitive domain, learning, as described by Zhao et al. (2014) includes the affective domain and the metacognitive domain. The focus of their work focuses on the metacognitive domain, characterized by students monitoring their learning processes through reflection and self-regulate (Zhao et al., 2014, p. 48). To effectively facilitate a metacognitive intervention, Zhao et al. administered an Effective Learning Strategies Survey that addressed levels of intellectual behavior and types of learning strategies (Zhao et al., 2014, p. 48). During the lecture following the administration of the first exam, students listed the top three reasons for their performance and also took the Effective Learning Strategies Survey. The following lecture introduced concepts of metacognition and a detailed procedure for exam preparation. At the end of the course, students answered the Effective Learning Strategies Survey to provide pre- and post-intervention data.

Approximately one-third of students, in both the Fall 2011 and Spring 2012 semesters, realized that Applying and Analyzing skills were necessary in college. The post-surveys showed that students' perceptions changed most dramatically for the role of Applying and Analyzing in college (89.6%) (Zhao et al., 2014, p. 50). Results for questions regarding learning strategies showed that students modified their exam and classroom preparation techniques following the intervention. The postsurvey results show a shift from in-class learning strategies, such as attending class on time and taking notes, to post-class learning strategies, such as joining study groups and reviewing all class materials prior to exams (Zhao et al., 2014, p. 50). Significant shifts were seen in responses to questions with the underlying notion of self-reflection.

Zhao and colleagues' work suggests a need for direct metacognition instruction in undergraduate general education. Not only did students' perception of learning behaviors change but also students' learning strategies and exam preparation strategies adjusted to their new understanding. Students actively engaged in effective learning strategies despite their increased workloads. Students who received metacognition instruction in both the fall and spring semesters also significantly outperformed their peers on all exams. Although the data for the first-time participants are contradictory in the fall versus the spring semester, the dual participant data further supports early instruction of metacognition in undergraduate education (Zhao et al., 2014, p. 52).

Students report utilizing a variety of study strategies in preparation for examinations even though very few options are formally discussed in classrooms. Commonly teachers provide study guides—to promote self-testing—and notes—to promote restudying or rereading. Teachers, however, often provide study strategies and resources that do not reflect best practices as suggested by education literature.

Regardless of if students are provided with proven best practices, students often do not internalize these strategies and instead may use strategies that do not yield desirable outcomes (Hartwig & Dunlosky, 2012, p. 126). Hartwig & Dunlosky present that students tend to prioritize whatever is due soonest, which means that students spend time studying for short-term tasks (quizzes) rather than long-term tasks (exams). The authors also present that students do not internalize the differential learning benefits of preparation and study activities (Hartwig & Dunlosky, 2012, p. 127) and thus students utilize the activities they are comfortable with.

Students in the study completed a 12-question study habit survey with forced responses, i.e. responses that were predetermined that students needed to choose from. Questions included a variety of aspects of studying such as time of day for studying, strategy utilization, and study patterns. Students also self-reported their GPAs on a 4.0 scale. However, selected the range of GPAs in which their actual GPA fell, since Hartwig and Dunlosky report that low achieving students often overestimate their GPAs (2012, p. 129).

Students self-reported that they do not study in a specific way because a teacher taught them how to study (Hartwig & Dunlosky, 2012, p. 128). 56% of students also responded that they study whatever is due the soonest before moving on to other work, which is supportive of prior work (Hartwig & Dunlosky, 2012, p. 128). Also supportive of past work is the statistic that the vast majority of students use self-testing through practice problems or flashcards; when given the opportunity to choose multiple study strategies 71% and 62% of respondents reported using practice problems and flashcards, respectively. Unexpectedly, students reported that their time of day study habits should improve; although 89% of students report studying in the evening or late night, 42% of students believe that morning or afternoon studying would be most effective (Hartwig & Dunlosky, 2012, p. 128).

Self-testing results were significantly related to GPA but only among individuals who responded that they completed practice problems (Hartwig & Dunlosky, 2012, p. 130). Using flashcards, therefore, was not correlated to GPA. Students commonly reported that they self-tested to determine how well they had learned information. The strategies that most accurately predicted GPA were self-testing, rereading, outline creation, and peer studying (Hartwig & Dunlosky, 2012, p. 131). Although type of study strategy may have varied among the academic cohorts, the planning of study time was not statistically significant in benefitting GPA. Hartwig and Dunlosky found that students who spaced out study time and students who crammed study time in at the last possible moment did not differ significantly in their GPAs (2012, p. 131).

Hartwig and Dunlosky's work suggests the need for two major shifts in education. The first is how educators and students utilize tests and study guides. Students in the current work reported that self-testing was a method of checking for understanding, rather than for encouraging learning. Although the two are similar, checking for understanding is the metacognitive foundation for new learning; once a student is aware of his or her struggles he or she should be dedicating more time to improve his or her struggles rather than splitting time between the mastered and unlearned content. Teachers may feel that they are unable to support this type of metacognitive skillfulness but the design of a study guide and the directions of a study guide can help facilitate improved metacognition. If study guides are grouped by content area or learning objective once a student has mastered one area he or she can move on to the next section without having to complete all of the problems.

The second shift that Hartwig and Dunlosky's work supports is a change in the way teachers present study skills and strategies. In the current work, students claim that they utilize strategies that aren't taught by teachers likely because teachers don't formally educate students about how to study nor do teachers formally present best practice study methods to students. Hartwig and Dunlosky found that self-testing through practice problems was the strategy most significantly correlated to GPA, suggesting a need for teachers to encourage the use of this strategy. The use of flashcards and highlighting, two strategies commonly reported by postsecondary students, did not significantly predict GPA and the findings should, therefore, be appropriately disseminated to students.

Students acquire a vast array of learning and study techniques throughout their educational journey. Study techniques are important because they are better calibrated than standardized tests and previous grades to student performance, as presented by Bartoszewski and Gurung (2015, p. 219). Bartoszewski and Gurung present findings on how much students use different learning techniques, how techniques are related to each other, and which techniques are best calibrated to high exam scores. Academic performance, however, isn't determined solely by study techniques; effort, ability, motivation, and perception influence students' academic performance. Bartoszewski and Gurung's work builds on prior learning technique literature by assessing students' use of ten learning strategies in a comprehensive study. The chosen learning strategies were: summarization, highlighting, keyword mnemonics, rereading, using imagery for text learning, elaborative interrogation, self-explanation, interleaved practice, practice testing, and distributed practicing. The authors also included nonacademic factors such as student ratings of the professor, procrastination, and self-efficacy since they may impact academic performance.

Overall, self-explanation, relating new information to old material, was the most utilized technique by students. Summarization, on the other hand, was the least utilized learning technique (2.535/5; Bartoszewski & Gurung, 2015, p. 222). When comparing the least utilized learning techniques, Bartoszewski and Gurung found significant differences in usage frequency. This was not prevalent among the most commonly used techniques.

An analysis of the comparative frequency of learning techniques found that students favor using more than one technique but don't necessarily favor one specific technique over the other (Bartoszewski & Gurung, 2015, p. 223). Students who engaged in robust, generalized learning techniques had higher ratings of their class and professor. Among the two classes surveyed, some strategies were also strongly correlated to exam scores. Practice testing, however, was the only strategy that had a positive relation with all exam scores between the two courses (Bartoszewski & Gurung, 2015, p. 223). Nonacademic factors also had significant correlation to exam performance; Students who procrastinated did more poorly on exams. The authors note that in the introduction to psychology course procrastination and exam performance was not significantly correlated potentially due to the importance of the final exam (Bartoszewski & Gurung, 2015, p. 223). Self-efficacy, lecture ratings, and professor ratings had a positive influence on exam scores. Class section, ACT score, and high school GPA significantly predicted exam performance and variance (Bartoszewski & Gurung, 2015, p. 225).

Bartoszewski and Gurung's work suggests, firstly, that study strategies can be ranked in a hierarchical structure with relation to their impact on exam outcome. Practice testing was the study strategy that had the most consistent positive relationship with exam outcome and, therefore, the design and utilization of study guides are valuable at all education levels. However, postsecondary instructors are not likely to provide such resources, and instead offer copies of the learning objectives from which students should study or create their own preparatory resources. The cause of the disparity between learning practices literature and postsecondary educational practices, however, may not be one-directional issue. College professors challenge students to think critically, analyze information, and develop transferrable skillsets, so the absence of traditional study guides at the postsecondary level may be an attempt at encouraging student reflection on the learning objectives for a course.

Implications

Current literature on the benefits of metacognition in secondary and postsecondary education present that improved metacognition leads to improved grades (Young & Fry, 2008) and improved awareness of self (Hartwig & Dunlosky, 2012). Although there is an abundance of evidence pertaining to the benefits of improved metacognition and the current literature presents measures for assessing metacognitive skillfulness of students (see De Bruin, Kok, Lobbestael, & de Grip, 2017; Gezer-Templeton, Mayhew, Korte, & Schmidt, 2017; Metzger, Smith, Brown, & Soneral, 2018), work that suggests courses of action to monitor metacognitive skillfulness and then develop individualized improvement plans is non-existent.

Educators understand the value of individualized, scaffolded support for students at the elementary and secondary levels but the value of this support seems to be downplayed at the postsecondary level. Potentially postsecondary educators believe that their students already have the tools to be successful at the college level although current literature suggests otherwise (Zhao et al., 2014). Metacognition has been proven to be effective in reducing the performance gap between high- and low-achieving students (Callender, Franco-Watkins, & Roberts, 2015) and metacognition can also compensate for aptitude gaps (Cooper & Sandi-Urena, 2009). These findings suggest that metacognitive instruction should formally exist in university curricula.

Exam wrappers have been utilized in postsecondary education to encourage students to look over their exam and reflect on why they received the grade that they did (Stephenson, Craig, Zingaro, Horton, Heap, & Huynh, 2017). However, evidence suggests that students often elect not to pick up their exams and those that do spend little time reviewing their performance (Gezer-Templeton et al., 2017; Stephenson et al., 2017). If instructors are able to present evidence of the value of reviewing exam performance, students are more likely to take initiative and improve their future performance (Winkelmes, 2013).

Exam wrappers, however, need further modifications to effectively improve students' performances on exams. Current exam wrappers help students identify areas for improvement in their exam preparations and also identify gaps between what the students perceived would be assessed on the exam versus what the exam actually assessed (see Gezer-Templeton et al., 2017; Metzger et al., 2018). Exam wrappers do not offer individualized feedback to students, nor do exam wrappers suggest courses of action for students to take in order to make meaningful adjustments to preparation techniques. Therefore, in their current state, exam wrappers heavily rely on the assumption that all students have strongly developed metacognitive skillfulness and can self-identify the best plan of action moving forward from one exam to another. The goal of this work is to develop a series of science exam wrappers that utilize current research on metacognitive skillfulness, and study strategies/exam preparation techniques to facilitate concrete courses of actions for users of exam wrappers and to facilitate metacognitive skillfulness through an assisted self-regulation tool.

Chapter Three: A Scaffolded Exam Wrapper Strategy

Rationale

College preparatory programs and schools are becoming increasingly more frequent in the United States. Due to high demand for developmental courses that seek to narrow the college-readiness gap, roughly one-third of all college students take remedial courses (Bowen, Chingos, & McPherson, 2009). Preparatory institutions and remedial courses importantly provide support for underrepresented groups, for whom traditional higher education systems fail to accommodate (Knaggs, Sondergeld, & Schardt, 2013). Preparatory institutions are tasked with providing developmental education, defined as "…programs and services that address academic preparedness, diagnostic assessment and placement, development of general and discipline-specific learning strategies, and affective barriers to learning," (National Association for Developmental Education, n.d., p. 3), to their students. Such programs and services aid both students who are underprepared for college expectations and to students who have been out of the classroom and need the opportunity to revisit skills and educational strategies (ACPA College Student Educators International, 2015).

College preparatory institutions develop not only academic skills but also the behaviors and strategies that support success in the postsecondary environment. Although some may argue with the definition, Mijares (2007) asserts that "students are 'college ready' when they have the *knowledge, skills, and behaviors* to complete a college course of study successfully, without remediation," (p. 1). Providing students with resources and supports assumes that students understand how to and will actively use such services; research suggests that students do not self-regulate their learning and are passive consumers of information (Chen, Chavez, Ong, & Gunderson, 2017; Zimmerman, 2011; Zimmerman & Martinez-Pons, 1998). Literature on student self-regulation also suggests that self-regulation is more successful when there are motivational strategies linked to the regulation behavior (Garcia & Pintrich, 1994; Zimmerman, 2002; Zimmerman, 2008). Therefore, if student-centered educational resources are to be effective the resources must confer a tangible benefit to the students.

This project seeks to provide empirical study and test preparation strategies that not only improve student assessment performance but also develop metacognitive and self-regulatory skills in learners. Specifically developed for science classes at a small—approximately 230 students—racially diverse, minority-majority preparatory school in the northeastern United States, the scaffolded exam wrapper strategy seeks to facilitate the use of study strategies that are linked to performance mastery goals outlined by the class learning objectives. The project has three goals:

1. To improve student metacognition
2. To facilitate student self-regulation
3. To provide empirically sound study strategies, linked to learning objectives, for students and educators to utilize in their preparations for classes and assessments

Goal 1: To improve student metacognition

The American Association for the Advancement of Science (AAAS), in its 2011 report titled *Vision and Change for Undergraduate Biology Education*, claims that "Biology in the 21st century requires that undergraduates learn how to integrate concepts across levels of organization and complexity and to synthesize and analyze information that connects conceptual domains," (p. ix). However, a growing set of research on metacognition indicates that students enter college unprepared to face the academic challenges of the college classroom (Cummings, 2015; Siegesmund, 2016), and may therefore be unable to accomplish the tasks suggested by the AAAS. According to Dr. David T. Conley, director of the Center for Educational Policy Research in the College of Education at the University of Oregon, college-ready students possess "sufficient mastery of key cognitive strategies, key content knowledge, academic behaviors, and contextual knowledge," (Conley, 2007, p.18). Furthermore, students can develop their metacognitive skills utilizing the same practice and feedback system that is common in learning content knowledge (Azevedo & Cromley, 2004; Palinscar & Brown, 1984).

One challenge associated with developing students' metacognitive skills is that these skills are not automatically transferred across contexts (Lovett, 2013). Teaching metacognitive skills as strategies that are applicable to all domains has also not been successful (Lizarraga, Baquedano, Mangado, & Cardelle-Elawar, 2009); as such, it is important to reframe metacognitive skills in domain-specific contexts. This work utilizes the exam wrapper as a broad-scale metacognition strategy but the exam wrapper is scaffolded to provide developmental and domain-specific support for students who may struggle to make the cognitive connections, otherwise.

Goal 2: To facilitate student self-regulation

As students progress through school, their academic workloads increase, which require increased levels of self-regulatory and mature behaviors (Steinberg, 2005). Barry Zimmerman, an expert on self-regulated learning (SRL), defines SRL as "the degree to which students are metacognitively, motivationally, and behaviorally active participants in their own learning process," (Zimmerman, 1986, p. 308). The key to Zimmerman's definition is that students must *proactively* engage in processes to acquire academic skills, such as goal setting and utilizing learning strategies (Zimmerman, 2008), to enable success in coursework. Furthermore, self-regulated learning has been linked to metacognition (Zimmerman & Moylan, 2009), and students who display self-regulating behaviors are often described as having high executive functioning skills or capabilities.

As previously presented, students who enroll in remediated college courses or college preparatory institutions may seriously lack robust executive functioning skills (Hackman & Farah, 2008). Research suggests that executive functioning skills account for more than two times more variation in final grades than does IQ (Duckworth & Seligman, 2005). Executive functioning skills can be improved, through diligent practice however; school curricula are shown to improve executive functioning, challenge executive functioning skills, and require students to continuously adapt to new situations (Diamond, Barnett, Thomas, & Munro, 2007; Lillard & Else-Quest, 2006; Riggs, Greenberg, Kusché, & Pentz, 2006). This work seeks to help students to develop executive functioning and academic self-regulatory behaviors in two ways: 1) highlight students' current self-regulatory behaviors and the tangible outcomes of students' current practices, in this case assessment scores; and 2) guide students toward vetted self-regulatory strategies to improve those tangible outcomes.

Goal 3: To provide empirically sound study strategies, linked to learning objectives, for students and educators to utilize in their preparations for classes and assessments

Students and instructors, alike, can benefit from vetted study and test preparation strategies. Although instructors regularly suggest study strategies that promote retention of information, a recent study on instructor and student knowledge of study strategies showed that instructors support strategies that do not have a strong evidential basis for enhancing learning (Morehead, Rhodes, & DeLozier, 2016). If students claim that they are rarely taught how to study (Hartwig & Dunlosky, 2012) and when students are given study strategies the strategies are not empirically-based (Morehead, Rhodes, & DeLozier, 2016), then teachers are failing to model strategies associated with effective learners.

Multiple studies on test preparation strategies of college students have shown that college students focus on what is due soonest and often lack the foresight needed to utilize empirical strategies (Kornell & Bjork, 2007; McCabe, 2011; Moorehead, Rhodes, & DeLozier, 2016). In light of such findings, teachers who provide students with assessment planning and evaluation mechanisms that are time efficient will likely see improvements in students' test performances. The challenge associated with introducing students to new preparation strategies is best summarized by a recent meta-analysis of five popular study strategies: "students appear to hold strong preferences for study techniques that they have used throughout their educational careers; consequently, attempts to sell them on new strategies may be met with resistance," (Miyatsu, Nguyen, & McDaniel, 2018, p. 390). College students may lack the ability to incorporate new study strategies due to the students' belief that the skills and strategies utilized in high school will be equally as effective in the college setting (Nordell, 2009).

Using the Exam Wrapper Modules

The following scaffolded exam wrapper modules are designed for an introductory college science course that takes place across a 32-week time frame. Each module represents an eight-week period of biology, chemistry I, chemistry II, or physics, and is split into two parts: module a for the midterm examination and module b for the final examination associated with the course. The modules contain scaffolded exam wrappers for students to utilize; the exam wrapper is a metacognitive tool that seeks to help students identify the test preparation strategies that helped and did not help students succeed on a given examination. Traditionally, as they were envisioned by Marsha Lovett, exam wrappers develop students' metacognitive skills as they actively consider and evaluate why their test preparations were or were not successful (Lovett, 2013). What Lovett's original work—and subsequent work by others (Gezer-Templeton et al., 2017; Metzger et al., 2018; Soicher & Gurung, 2017)—fails to accomplish is providing scaffolded support leading up to and immediately following the examination.

The exam wrapper strategy that is presented here extends Lovett's 2013 work by providing a scaffolded metacognitive instrument that defines
the test preparation steps that students should accomplish prior to taking the exam and supports empirical test preparation strategies linked to learning objectives. In this scaffolded exam wrapper, the students' test preparation strategies are guided by Sherrie Nist and Michele Simpson's PLAE strategy (1984). The PLAE strategy—preplanning, listing, activating, and evaluating—is a self-regulatory strategy to assist students in preparing for and assessing their test performance. One challenge of utilizing the PLAE strategy is that the authors do not include a template or tool to follow when implementing the strategy; instead, the PLAE strategy is a theory defined by its four steps. The scaffolded exam wrapper strategy melds the PLAE strategy and exam wrapper strategy together to provide explicit templates for students to utilize when preparing for exams and evaluating their performance and preparation strategies.

Shown in the following modules, the preplanning step of the scaffolded exam wrapper focuses students on the layout, design, and content of the examination. Students complete the preplanning page to track how they will be assessed and what content they will be assessed on. The listing step of the scaffolded exam wrapper requires students to make a study plan for themselves and identify what strategies they will use to prepare for the examination. The listing step can include broad preparation themes, such as planned study sessions, or explicit strategies that students will use to prepare for the examination. The listing step of the scaffolded exam wrapper is interwoven with the third step, activating. The activating step is seen in the modules as a checklist for students to utilize when they complete each test preparation strategy that they have listed in the listing step. A step that is not included in the original PLAE strategy is taking, as in taking the exam. Although Nist and Simpson probably believed that taking the exam is implicit to their strategy, it is important to remind students what they are striving toward and why they have put in the work. The final step of the modules is the evaluation step. The evaluation step combines Nist and Simpson's goal of self-reflection with a tool that encourages students to honestly evaluate their performance flaws and successes. The exam wrapper not only asks students to qualitatively evaluate their test preparation but also asks students to identify the learning objectives they did not successfully master. The final page of each module utilizes Bloom's Taxonomy to categorize the learning objectives from each examination and direct students to test preparation strategies that support the performance mastery of each learning objective.

Module 1: Biology

The exam wrappers for the biology modules, 1a and 1b, have been specifically customized to reflect literature about test preparation for introductory biology. Biology courses, specifically introductory biology courses, are often characterized by the two lowest levels of Bloom's Taxonomy: remembering and understanding (Wood, 2009). According to a longitudinal study of undergraduate biology assessments, of the 9713 questions submitted by 50 teaching faculty, 93% were rated at the lower-order cognitive skills (LOCS) level (Momsen, Long, Wyse, & Ebert-May, 2010). Although a major goal in science education is to develop process skills (AAAS, 2011), and to do so relies on higher-order cognitive skills (HOCS), instructors may argue that introductory biology courses focus on developing the foundational knowledge on which higher-order thinking relies, and as such it is appropriate to utilize LOCS in introductory biology courses. Instructors may also cite the enrollment rate in introductory biology courses, potentially 600-1,000 students per year (Smith et al., 2005), and the time and space requirements to facilitate meaningful process skill instruction as obstacles for assessing HOCS. A challenge with introductory level biology courses and the large lecture models they utilize is that students develop their own understanding of biology concepts through lecture information; Chi et al. (1989) makes a clear delineation between students' perceived understanding of biology concepts through instructor explanations and students' actual understanding of concepts through self-explanation activities during studying.

Although the literature does not directly suggest that certain preparation strategies should be utilized for biology, a combination of the LOCS level of introductory biology (Momsen et al., 2010) and literature on linking Bloom's Taxonomy to test preparation strategies (Crowe, Dirks, & Wenderoth, 2008) provide necessary guidance. According to Crowe and colleagues, study and preparation strategies that are linked to the remembering and understanding taxa of Bloom's levels of performance mastery include defining vocabulary, self-assessing knowledge, developing concept maps, and categorizing features, functions, or terminology, to name a few. A comprehensive list can be found at the end of module 1a. Defining vocabulary and internalizing the definitions are regarded as important preparation strategies for introductory biology because the course is full of discipline-specific terms, as each lecture period often introduces a new sub-discipline of the largely branched field of science (Nordell, 2009). Developing concept maps is the other preparation strategy that is biology-specific; its use does not serve students in preparing for chemistry or physics examinations. Concept maps are effective note condensing tools, which have been positively correlated with higher exam grades (Rodriguez, Rivas, Matsumura, Warschauer, & Sato, 2018), and address the complex, yet interrelated, breadth of introductory biology courses.

Although the use of learning objectives to prepare for exams is not a strategy specific to introductory biology, it may be one of the most beneficial strategies, as students utilize multiple lower-order cognitive skills but also develop questions based on the learning objectives—a higher-order cognitive skill. A recent study on how undergraduate science students use learning objectives to prepare for examinations found that nearly 72% of students utilized learning objectives to study for exams and that 96% of those students felt that the learning objectives aligned well to very well with the exam questions (Osueke, Mekonnen, & Stanton, 2018). Work done in the United Kingdom on undergraduate usage of learning objectives for studying found that students perceived learning objectives as helpful, but the learners were unsure of the performance mastery required to satisfy each objective (Brooks, Dobbins, Scott, Rawlinson, & Norman, 2014). In this work, however, learning objectives and study strategies are paired with Bloom's performance mastery levels to provide students with support lacking in Brooks and colleagues' work.

Module 1a: Biology Midterm Examination

Pre-Plan: Gather information about the exam	
	Biology
When and where is the exam? How much time do I have to take it?	
How much is the exam worth (% of midterm and final grade)?	
Identify: • Types of questions on exam • Expected level of learning • Number of each type and point value	
Identify material (i.e., topics, sections) exam will cover and where you will find it (e.g., text, notes, quizzes).	
How do you think you will perform on the exam (percentage)? *to be completed the night before the exam	
How do you think you performed on the exam (percentage)? *to be completed immediately following the exam	

List Strategies and Activate Plan		
Date	**<u>Learning Strategies</u>:** How, when where, and with whom will you study?	**Done**

Take Exam

Evaluate Plan Using Feedback: Exam Wrapper			
Directions: Evaluate your exam preparation habits and performance according to the following statements.			
Exam Grade: _______ Overall Grade: _______	Great job!	Not too bad	Needs work
Completed homework consistently.			
Consistently checked quality of homework for proficiency.			
Displayed active involvement in class (paid attention, engaged in group work/POGIL activities, asked questions).			
Created clear, detailed notes that addressed lesson objectives (ALOs).			
Read and utilized textbook resources.			
Regularly reviewed material throughout the quarter.			
Studied the appropriate material for the exam.			
Used study methods appropriate to the exam.			
Self-regulated my study environment.			
Got help if I needed it (AI, peers, SOS, etc.).			
Spent enough time studying.			
Distributed study time instead of cramming.			
Predicted exam questions.			
Felt confident going into the exam.			
Understood the exam directions.			
Felt confident during the exam.			
Reviewed the exam before turning it in.			
Felt confident after completing the exam.			

1. What part of your preparation (strategies) helped you **most** on the exam?

2. What part of your preparation (strategies) helped you **least** on the exam?

3. How will you improve upon your preparation and/or engagement during the second half of the quarter? Highlight areas that you identified as "needs work." Be specific: the strategies you use should be linked to the mastery level assessed by each question. Refer to the learning objective map on the next pages and the Bloom's Taxonomy table on to help.

Adapted from:
Nist, S. & Simpson, M. (1989). PLAE. A validated study strategy. *Journal of Reading, 33,* 182-186.
Seller, D., Dochen, C., & Hodges, R. (2015). *Academic transformation: The road to college success.* (3rd ed.). Boston, MA: Pearson.

Assessed Learning Objectives

1.1 Identify the essential components of prokaryotic and eukaryotic cells.
1.2. Identify the major structural differences between an animal and plant cell.
1.3. Compare and contrast the structure of prokaryotes and eukaryotes.
1.4. Identify the three major shape of bacterial cells.

2.1. Recognize and state the function of basic cell organelles.
2.2. Describe the relationship among the functions of various organelles.
2.3 Recognize and state the function of the organelles in a plant cell that are different from an animal cell.
2.4 To gain more experience using the microscope, and in particular, to learn how to use the oil immersion lens.
2.5 Know which organelles are visible using a light microscope.

3.1. Label and understand the parts of the cell cycle. Order the phases within the cell cycle.
3.2. Recognize mitosis as part of the cell cycle.
3.3. List the phases of mitosis and summarize the events that occur during each phase.
3.4. Explain the importance of mitosis in the life of a cell and for the survival of the organism.

4.1. Explain the stages of meiosis and how haploid cells are produced for reproduction.
4.2. Explain how fertilization restores the diploid number and how meiosis maintains the diploid number across generations.
4.3. Explain what happens to chromosomes during meiosis and in which cells meiosis occurs.
4.4. Describe how meiosis results in genetic variation.

5.1. Draw a simple representation of a nucleotide and name each of the three components.
5.2. Apply the base-pair rule to show how the 2 strands of DNA molecules are joined.
5.3. Label a DNA molecule to demonstrate that the molecule is made of two antiparallel stands of nucleotides which are oriented to create a sugar-phosphate backbone and base rungs.
5.4. Describe the steps to DNA replication in the semi-conservative model.
5.5. Determine the relationship between the nucleus, chromosomes, genes, and DNA.

6.1. List the events that occur during the transcription of DNA into mRNA.
6.2. Describe the purpose of the removal of introns and addition of a methyl cap and poly-A tail in the processing of the eukaryotic pre-RNA.
6.3. Explain the relationship among DNA, mRNA, mRNA codons, tRNA anticodons, and amino acids.
6.4. List the events that occur during translation.
6.5. Describe the advantages to an organism for having several codons for a specific amino acid.

7.1. Identify a gene mutation as a substitution, insertion, or deletion.
7.2. Predict the effect of neutral, positive, and negative mutations at the cellular level and organism level.
7.3. State that mutations are the basis of evolution.

	Learning Objectives									
	1.1	1.2	1.3	1.4	2.1	2.2	2.3	2.4	2.5	3.1
Questions Aligned with Learning Objectives	5	6	4 7 24	1 2 3	8 12 13 14 15 21 23	10 11 19	16 17 18 20		9 22	37 68 69
Number of Questions Answered Incorrectly										

	Learning Objectives									
	3.2	3.3	3.4	4.1	4.2	4.3	4.4	5.1	5.2	5.3
Questions Aligned with Learning Objectives	26	29 76	25 28 40	35 75	36 72 77 80	30 32 33 74	31 34 41	44	45 49 51	46 78 79
Number of Questions Answered Incorrectly										

	Learning Objectives									
	5.4	5.5	6.1	6.2	6.3	6.4	6.5	7.1	7.2	7.3
Questions Aligned with Learning Objectives	47 64 73	39	59 61 65	62 66	48 50 56 58 60 67 71	27 63 70		52 53 54	42 43 55 57	
Number of Questions Answered Incorrectly										

Bloom's Taxonomy, Learning Objectives, and Study Strategies

Bloom's Level of Mastery	Learning Objectives	Study Strategies
Remembering	1.1, 1.2, 1.4, 2.1, 2.3, 2.5, 3.2, 3.3, 5.1, 6.1, 6.4, 7.1, 7.3	Practice labeling diagrams; list characteristics; identify biological objects or components from flash cards; draw, classify, select, or match items; write out the textbook definitions; take a practice test
Understanding	1.3, 2.2, 3.1, 3.4, 4.1, 4.2, 4.3, 4.4, 5.3, 5.4, 6.2, 6.3, 6.5	Describe a process in your own words; provide examples of a process; write a sentence utilizing vocabulary; peer vocabulary quizzes
Applying	5.2	Review a process and describe what would happen if you alter the activity of a component in the system; peer-teach; critique a peer's presentation of content
Analyzing		
Evaluating	5.5	
Creating	7.2	Create a concept map that connects multiple processes; develop your own test questions

Module 1b: Biology Final Examination

Pre-Plan: Gather information about the exam	
	Biology
When and where is the exam? How much time do I have to take it?	
How much is the exam worth (% of final grade)?	
Identify: • Types of questions on exam • Expected level of learning • Number of each type and point value	
Identify material (i.e., topics, sections) exam will cover and where you will find it (e.g., text, notes, quizzes).	
How do you think you will perform on the exam (percentage)? *to be completed the night before the exam	
How do you think you performed on the exam (percentage)? *to be completed immediately following the exam	

List Strategies and Activate Plan		
Date	**<u>Learning Strategies</u>:** How, when where, and with whom will you study?	**Done**

Take Exam

Evaluate Plan Using Feedback: Exam Wrapper			
Directions: Evaluate your exam preparation habits and performance according to the following statements.			
Exam Grade: _______ Overall Grade: _______	Great job!	Not too bad	Needs work
Completed homework consistently.			
Consistently checked quality of homework for proficiency.			
Displayed active involvement in class (paid attention, engaged in group work/POGIL activities, asked questions).			
Created clear, detailed notes that addressed lesson objectives (ALOs).			
Read and utilized textbook resources.			
Regularly reviewed material throughout the quarter.			
Studied the appropriate material for the exam.			
Used study methods appropriate to the exam.			
Reviewed my midterm exam to learn from my previous mistakes.			
Self-regulated my study environment.			
Got help if I needed it (AI, peers, SOS, etc.).			
Spent enough time studying.			
Distributed study time instead of cramming.			
Predicted exam questions.			
Felt confident going into the exam.			
Understood the exam directions.			
Felt confident during the exam.			
Reviewed the exam before turning it in.			
Felt confident after completing the exam.			

1. What part of your preparation (strategies) helped you **most** on the exam?

2. What part of your preparation (strategies) helped you **least** on the exam?

3. What changes did you make to test preparation strategies and how did the changes that you made to your test preparation from the midterm examination to the final examination benefit or hinder your performance? Did you align your preparation strategies to the learning objectives?

Adapted from:
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Seller, D., Dochen, C., & Hodges, R. (2015). *Academic transformation: The road to college success.* (3rd ed.). Boston, MA: Pearson.

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2.1. Recognize and state the function of basic cell organelles.
2.2. Describe the relationship among the functions of various organelles.
2.3 Recognize and state the function of the organelles in a plant cell that are different from an animal cell.
2.4 To gain more experience using the microscope, and in particular, to learn how to use the oil immersion lens.
2.5 Know which organelles are visible using a light microscope.

3.1. Label and understand the parts of the cell cycle. Order the phases within the cell cycle.
3.2. Recognize mitosis as part of the cell cycle.
3.3. List the phases of mitosis and summarize the events that occur during each phase.
3.4. Explain the importance of mitosis in the life of a cell and for the survival of the organism.

4.1. Explain the stages of meiosis and how haploid cells are produced for reproduction.
4.2. Explain how fertilization restores the diploid number and how meiosis maintains the diploid number across generations.
4.3. Explain what happens to chromosomes during meiosis and in which cells meiosis occurs.
4.4. Describe how meiosis results in genetic variation.

5.1. Draw a simple representation of a nucleotide and name each of the three components.
5.2. Apply the base-pair rule to show how the 2 strands of DNA molecules are joined.
5.3. Label a DNA molecule to demonstrate that the molecule is made of two antiparallel stands of nucleotides which are oriented to create a sugar-phosphate backbone and base rungs.
5.4. Describe the steps to DNA replication in the semi-conservative model.
5.5. Determine the relationship between the nucleus, chromosomes, genes, and DNA.

6.1. List the events that occur during the transcription of DNA into mRNA.
6.2. Describe the purpose of the removal of introns and addition of a methyl cap and poly-A tail in the processing of the eukaryotic pre-RNA.
6.3. Explain the relationship among DNA, mRNA, mRNA codons, tRNA anticodons, and amino acids.
6.4. List the events that occur during translation.
6.5. Describe the advantages to an organism for having several codons for a specific amino acid.

7.1. Identify a gene mutation as a substitution, insertion, or deletion.
7.2. Predict the effect of neutral, positive, and negative mutations at the cellular level and organism level.
7.3. State that mutations are the basis of evolution.

8.1. Explain the origin of similar traits in families as the passing on of genes in the DNA of ancestors.
8.2. Compare and contrast the homologous bone structure of diverse organisms to show related ancestry.
8.3. Use DNA comparison to support relatedness between species through evolution.
8.4. Group different organisms in to six kingdoms and three domains using simple characteristics.
8.5. Recognize how a scientific name is written and to what each part of the name refers.
8.6. Identify eight taxonomic levels of organization and use these to determine relatedness of different organisms.

9.1. Explain how populations of organisms can change over a period of time (i.e. how populations evolve).
9.2. Distinguish between natural selection (evolution that is the result of environmental changes) and artificial selection (evolution that is the direct result of human choices).
9.3. Distinguish between human-caused natural selection and deliberate selection of specific traits by humans (artificial selection).

10.1. Define three types of selection that can occur due to environmental pressures.
10.2. Identify the selection process that occurs as a result of a given environmental pressure.
10.3. Identify the evolutionary process that occurs as a result of random gene fluctuations (genetic drift).
10.4. Distinguish between genetic drift and natural selection.
10.5. Use reproductive isolation as a criterion to determine if individuals from two different populations are the same of different species.

11.1. Use a phylogenetic tree or evolutionary tree to compare relatedness and divergence of species.
11.2. Compare amino acid sequence of known proteins between species and calculate the sequence divergence to determine relatedness.
11.3. Compare and contrast a phylogenetic tree to a cladogram.

12.1. Describe different patterns of distribution and density and the factors that cause them.
12.2. Distinguish between density-dependent and density-independent factors.
12.3. Express the changes in the size of a population through mathematical equations with variables for births, deaths, immigration and emigration.
12.4. Discuss several ways in which species populations compensate for low survivorship or manage to obtain high survivorship.
12.5. Relate environmental factors such as limited resources and space to the growth and stabilization (carrying capacity) of a population.
12.6. Distinguish between the three survivorship curve types: type I, type II and type III.

13.1. Explain the cyclic relationship between predator and prey population sizes.
13.2. Identify and define the three types of symbiotic relationships.
13.3. Differentiate between inter- and intra-specific competitions.
13.4. Outline the paths of carbon, nitrogen, and water through the ecosystem.
13.5. Explain how the recycling of nutrients sustains life on Earth.
13.6. Predict the effects on living organisms when the nutrient cycles are disrupted.

14.1. Recognize and understand some of the variables that affect climate change and the effects of climate change. (i.e. average surface temperatures and Artic ice declines).
14.2. Analyze some of the valid scientific data on climate change from IPCC researchers in graphical form.

	Learning Objectives									
	1.1	1.2	1.3	1.4	2.1	2.2	2.3	2.4	2.5	3.1
Questions Aligned with Learning Objectives	10		82		73 83					6 87
Number of Questions Answered Incorrectly										

	Learning Objectives									
	3.2	3.3	3.4	4.1	4.2	4.3	4.4	5.1	5.2	5.3
Questions Aligned with Learning Objectives	4	84			1 5				11 80	
Number of Questions Answered Incorrectly										

	Learning Objectives									
	5.4	5.5	6.1	6.2	6.3	6.4	6.5	7.1	7.2	7.3
Questions Aligned with Learning Objectives		3	7 52 72 81		9 12 13			2		8 16
Number of Questions Answered Incorrectly										

	Learning Objectives									
	8.1	8.2	8.3	8.4	8.5	8.6	9.1	9.2	9.3	10.1
Questions Aligned with Learning Objectives	31	18 19	17	30 76 77 78 79	15	21 64	14 24 25 28 39	26 33 37	35	85B
Number of Questions Answered Incorrectly										

	Learning Objectives									
	10.2	10.3	10.4	10.5	11.1	11.2	11.3	12.1	12.2	12.3
Questions Aligned with Learning Objectives	40 43 85A	23 29 60	36	41 49	44 45 46 86	69		55 56	34 57	58 59
Number of Questions Answered Incorrectly										

	Learning Objectives										
	12.4	12.5	12.6	13.1	13.2	13.3	13.4	13.5	13.6	14.1	14.2
Questions Aligned with Learning Objectives	88	20 48 65	74 75	53	50 66 67 68	22 54	32 38 70 71	51		42 47 61 62 63	27
Number of Questions Answered Incorrectly											

Bloom's Taxonomy, Learning Objectives, and Study Strategies

Bloom's Level of Mastery	Learning Objectives	Study Strategies
Remembering	1.1, 1.2, 1.4, 2.1, 2.3, 2.5, 3.2, 3.3, 5.1, 6.1, 6.4, 7.1, 7.3, 8.5, 8.6, 10.1, 10.2, 10.3, 12.1, 12.2, 13.2, 13.4, 14.1,	Practice labeling diagrams; list characteristics; identify biological objects or components from flash cards; draw, classify, select, or match items; write out the textbook definitions; take a practice test
Understanding	1.3, 2.2, 3.1, 3.4, 4.1, 4.2, 4.3, 4.4, 5.3, 5.4, 6.2, 6.3, 6.5, 8.1, 8.2, 8.4, 9.1, 9.2, 9.3, 10.4, 11.3, 12.3, 12.4, 12.6, 13.1, 13.3, 13.5	Describe a process in your own words; provide examples of a process; write a sentence utilizing vocabulary; peer vocabulary quizzes
Applying	5.2, 8.3, 10.5, 11.1, 11.2, 12.5	Review a process and describe what would happen if you alter the activity of a component in the system; peer-teach; critique a peer's presentation of content
Analyzing	5.5, 13.6, 14.2	Compare and contrast two ideas or concepts
Evaluating		
Creating	7.2	Create summary sheets that show how facts and concepts relate to each other; create your own practice test questions

Modules 2 and 3: Chemistry I and II

The exam wrappers for the chemistry modules 2a, 2b, 3a, and 3b, have been specifically customized to reflect literature about test preparation for introductory chemistry. Chemistry, and specifically introductory chemistry, is known as the central science, since mastering the principles of matter and atomic structure is essential for further coursework in science (Tai, Sadler, & Loehr, 2004). Although significant evidence does not exist to support chemistry performance as a predictor of college science performance (Sadler & Tai, 2007), poor performance in introductory chemistry can hinder a student's continuation in his or her major curriculum, since introductory chemistry is often a prerequisite for upper level science courses (Tai, Sadler, & Loehr, 2004).

One of the major challenges about teaching introductory chemistry at the college level is the difference in students' prior knowledge. Although post-secondary instructors will argue that prior knowledge differentials are a challenge for all college instructors, literature in chemistry continues to support the role of prior chemistry knowledge in the success of chemistry students and science majors (National Research Council Chemical Sciences Roundtable, 2009; Seery, 2009; Seery & Donnelly, 2012). According to data gathered in 2007 by the Council of Chief State School Officers, high school enrollment in chemistry courses prior to graduation is highly variable; in Texas, 87% of students take chemistry before graduating, while only 13% of students in West Virginia complete chemistry before leaving school (Blank, Langesen, & Petermann, 2007). Data from the recent High School Transcript

Study (HSTS) conducted by the U.S. Department of Education also helps establish the importance of high school chemistry in the overall academic performance of students. According to the HSTS, the average scores on the National Assessment of Educational Progress (NAEP) were significantly higher for students whose highest level of science completed in ninth grade was chemistry, compared to biology or earth science (Nord et al., 2011).

The importance of students' cognitive abilities in chemistry cannot be understated. Researchers and professors have identified that higher-order cognitive functions enable students to transfer their knowledge across courses, apply academic information to a changing world, and approach new challenges that arise (Bransford, Donovan, & Pellegrino, 2004; Hart Research Associates, 2013; Perkins & Salomon, 1992). In chemistry, students' cognitive abilities may be better predictors of academic success than standard college readiness assessments. An investigation into students' formal thought abilities and general achievement found that formal operation thought, the last stage of cognitive development (Inhelder & Piaget, 1958), is necessary for success in introductory college chemistry (Lewis & Lewis, 2007).

If introductory chemistry is such an intellectually demanding course and the coursework is necessary for student success in college science programs, then instructors of introductory chemistry courses should utilize empirical strategies that develop students as self-regulated learners. The emphasis of introductory biological sciences, as previously stated, is factual recall of large masses of information due to the high volume of vocabulary and new concepts introduced that are to be carried over to later studies. While students may utilize text resources to gain a better understanding of lecture materials, as suggested by Lopez et al. (2013), chemistry textbooks contain more vocabulary words per page than the recommended level for foreign language courses (Groves, 1995). Therefore, the strategies that students utilize to strengthen their learning in chemistry need to be different from those utilized in biology. As denoted by the Bloom's Taxonomy, learning objectives, and study strategies charts for the chemistry modules, the focus of the introductory chemistry course in this work is understanding, applying, and analyzing information, rather than remembering and understanding in the biology course. The associated study strategies reflect the shift in performance mastery and require a discussion-focused, group approach to learning, rather than a silent, individual approach.

The exam wrapper itself is modified from the biology exam wrapper in two ways: the first is the removal of "read and utilized textbook resources," and the second is the addition of "completed practice problems associated with the lesson objectives" and "understood how to use and utilized the reference data card (RDC)." As already mentioned, college chemistry textbooks often do not sync with students' expectations of textbooks as resources to gain better understandings of class lectures. Especially in the introductory chemistry course that is the focus of this work, the textbook can be utilized as a supplemental resource but when students are engaged in guided inquiry learning, textbook materials don't support active learning. A more effective strategy to actively engage students in chemistry material is the utilization of practice problems associated with learning objectives (Karpicke & Blunt, 2011).

Karpicke and Blunt showed that practice testing or retrieval practice, as they called it, was more effective than studying in a single setting, more effective than studying the same material on four separate occasions, and more effective than studying the material and developing a concept map to organize thoughts and ideas.

Students' understanding of how to use and their utilization of the chemistry reference data card (RDC) is essential for success in the course. The RDC is a resource that provides students with formulas, simple conversion factors, and a periodic table. Approximately one-third of the exam questions on the midterm and one-half of the exam questions on the final examination require use of the RDC, which justifies the assessment of students' usage of the RDC in the exam wrapper.

A preparation strategy that is unique to the chemistry curriculum is solving practice word problems using the GFPSR problem-solving method. Given-find-plan-solve-reflect [GFPSR] is a scaffolded approach to problem-solving that is broadly based on Polya's (1957) *How to Solve It: A New Aspect of Mathematical Method*, which presents a framework to teaching and assessing problem-solving skills. The GFPSR method helps students to organize their thoughts about a mathematical problem, develop a plan of attack, and reflect on the end results of the process. Although the GFPSR method is not critical for student success in solving mathematical problems, students with low executive functioning skills can find comfort in having a step-wise plan for approaching word problems.

Module 2a: Chemistry I Midterm Examination

Pre-Plan: Gather information about the exam	
	Chemistry
When and where is the exam? How much time do I have to take it?	
How much is the exam worth (% of final grade)?	
Identify: • Types of questions on exam • Expected level of learning • Number of each type and point value	
Identify material (i.e., topics, sections) exam will cover and where you will find it (e.g., text, notes, quizzes).	
How do you think you will perform on the exam (percentage)? *to be completed the night before the exam	
How do you think you performed on the exam (percentage)? *to be completed immediately following the exam	

List Strategies and Activate Plan		
Date	**<u>Learning Strategies</u>:** How, when where, and with whom will you study?	**Done**

Take Exam

Evaluate Plan Using Feedback: Exam Wrapper			
Directions: Evaluate your exam preparation habits and performance according to the following statements.			
Exam Grade: _______ Overall Grade: _______	Great job!	Not too bad	Needs work
Completed homework consistently.			
Consistently checked quality of homework for proficiency.			
Displayed active involvement in class (paid attention, engaged in group work/POGIL activities, asked questions).			
Created clear, detailed notes that addressed lesson objectives (ALOs).			
Completed practice problems associated with the lesson objectives.			
Regularly reviewed material throughout the quarter.			
Studied the appropriate material for the exam.			
Used study methods appropriate to the exam.			
Understood how to use and utilized the Chemistry Reference Data Card (RDC).			
Self-regulated my study environment.			
Got help if I needed it (AI, peers, SOS, etc.).			
Spent enough time studying.			
Distributed study time instead of cramming.			
Predicted exam questions.			
Felt confident going into the exam.			
Understood the exam directions.			
Felt confident during the exam.			
Reviewed the exam before turning it in.			
Felt confident after completing the exam.			

1. What part of your preparation (strategies) helped you **most** on the exam?

2. What part of your preparation (strategies) helped you **least** on the exam?

3. How will you improve upon your preparation and/or engagement during the second half of the quarter? Highlight areas that you identified as “needs work.” Be specific: the strategies you use should be linked to the mastery level assessed by each question. Refer to the learning objective map on the next pages and the Bloom’s Taxonomy table on to help.

Adapted from:
Nist, S. & Simpson, M. (1989). PLAE. A validated study strategy. *Journal of Reading, 33*, 182-186.
Seller, D., Dochen, C., & Hodges, R. (2015). *Academic transformation: The road to college success.* (3rd ed.). Boston, MA: Pearson.

Assessed Learning Objectives

1.1 Determine the number of significant digits that should be recorded in a measurement when given the measuring tool.
1.2. Convert from one temperature scale to another.

2.1. Determine which zeros in a recorded measurement are significant.
2.2. Express the values of measurements and calculations using the correct number of significant digits.
2.3 Convert numbers between standard notation and scientific notation.

3.1. Convert metric system measurements into related units.
3.2. Generate conversion factors from equivalencies that are used for unit conversion and dimensional analysis.
3.3. Report all measurements and calculated values so that each number reported contains *magnitude*, *uncertainty*, and *units*.
3.4. Use GFPSR to solve mathematical problems.

4.1. Determine the number of atoms in a molecule or compound by reading a chemical formula.
4.2. Classify matter as a pure substance or a mixture.
4.3. Classify pure substances as elements or compounds.
4.4. Correlate particle motion with the different states of matter and its relationship to kinetic energy.
4.5. Understand all phase change processes and their energy requirements.
4.6. Predict how the density of a substance changes with external heating/cooling.

5.1. Know that specific heat of a substance is an intrinsic property of all matter and changes when the state of matter changes.
5.2. Understand how heat capacity is related to the specific heat of a substance and the factors that influence both.
5.3. Interpret a heating/cooling curve and describe how it relates to specific heat.
5.4. Solve mathematical problems involving specific heat and heat capacity.

6.1. Determine the number of protons and neutrons in an atom based on the atomic symbol.
6.2. Describe the similarities and differences between isotopes and the parent atom.
6.3. Understand how an ion is formed and how it differs from the neutral, parent atom.
6.4. Use the terms cation and anion when describing ions generated from metals and non-metals, respectively.

7.1. Analyze how a heating/cooling curve graph displays the phase changes of matter.

	Learning Objectives									
	1.1	1.2	2.1	2.2	2.3	3.1	3.2	3.3	3.4	4.1
Questions Aligned with Learning Objectives	SA 1	55 56 57	6 18 30 52	10 21 24 53	*	5 7 8 9 12	54	*	SA 1	48
Number of Questions Answered Incorrectly										

	Learning Objectives									
	4.2	4.3	4.4	4.5	4.6	5.1	5.2	5.3	5.4	6.1
Questions Aligned with Learning Objectives	3 13 18 37	1 2 4 23 27 36	15 20 29 32 44 45 SA 2a, 2b	11 16 22 25 26 31 46 49 50 51	14 17 28 47 SA 2c, 2d, 2e	*	*	34 35	33 SA 3	60 61 62 63 65 69 70
Number of Questions Answered Incorrectly										

	Learning Objectives									
	6.2	6.3	6.4	7.1						
Questions Aligned with Learning Objectives	58 64 66	59 67 68		38 39 40 41 42 43						
Number of Questions Answered Incorrectly										

*Learning objectives marked with an asterisk are foundational requirements for other learning objectives and are not individually assessed.

Bloom's Taxonomy, Learning Objectives, and Study Strategies

Bloom's Level of Mastery	**Learning Objectives**	**Study Strategies**
Remembering	2.1, 3.3, 4.1, 5.1, 6.1	Identify chemical objects or components from flash cards; self-testing; draw, classify, select, or match items; write out the textbook definitions
Understanding	1.1, 2.2, 4.2, 4.3, 4.4, 4.5, 5.2, 6.2, 6.3	Describe a process in your own words; provide examples of a process; write a sentence utilizing vocabulary; peer vocabulary quizzes; define components and variables of a given equation
Applying	1.2, 2.3, 3.1, 3.2, 3.4, 4.6, 5.3, 5.4, 6.4	Review a process and describe what would happen if you alter the activity of a component in the system; peer-teach; peer critique of content presentation; discuss a real-world example of a concept covered in class; solve practice word problems using GFPSR problem-solving method
Analyzing	7.1	Compare and contrast two ideas or concepts; create a map of the main concepts by defining the relationships of the concepts using one- or two-way arrows
Evaluating		
Creating		

Module 2b: Chemistry I Final Examination

Pre-Plan: Gather information about the exam	
	Chemistry
When and where is the exam? How much time do I have to take it?	
How much is the exam worth (% of final grade)?	
Identify: • Types of questions on exam • Expected level of learning • Number of each type and point value	
Identify material (i.e., topics, sections) exam will cover and where you will find it (e.g., text, notes, quizzes).	
How do you think you will perform on the exam (percentage)? *to be completed the night before the exam	
How do you think you performed on the exam (percentage)? *to be completed immediately following the exam	

List Strategies and Activate Plan		
Date	**Learning Strategies:** How, when where, and with whom will you study?	**Done**

Take Exam

Evaluate Plan Using Feedback: Exam Wrapper			
Directions: Evaluate your exam preparation habits and performance according to the following statements.			
Exam Grade: _______ Overall Grade: _______	Great job!	Not too bad	Needs work
Completed homework consistently.			
Consistently checked quality of homework for proficiency.			
Displayed active involvement in class (paid attention, engaged in group work/POGIL activities, asked questions).			
Created clear, detailed notes that addressed lesson objectives (ALOs).			
Completed practice problems associated with the lesson objectives.			
Reviewed my midterm exam to learn from my previous mistakes.			
Studied the appropriate material for the exam.			
Used study methods appropriate to the exam.			
Understood how to use and utilized the Chemistry Reference Data Card (RDC).			
Self-regulated my study environment.			
Got help if I needed it (AI, peers, SOS, etc.).			
Spent enough time studying.			
Distributed study time instead of cramming.			
Predicted exam questions.			
Felt confident going into the exam.			
Understood the exam directions.			
Felt confident during the exam.			
Reviewed the exam before turning it in.			
Felt confident after completing the exam.			

1. What part of your preparation (strategies) helped you **most** on the exam?

2. What part of your preparation (strategies) helped you **least** on the exam?

3. What changes did you make to test preparation strategies and how did the changes that you made to your test preparation from the midterm examination to the final examination benefit or hinder your performance? Did you align your preparation strategies to the learning objectives? How will you utilize what you have learned in the first half of the chemistry course to maintain or improve your success in the second half of the chemistry course?

Adapted from:
Nist, S. & Simpson, M. (1989). PLAE. A validated study strategy. *Journal of Reading, 33,* 182-186.
Seller, D., Dochen, C., & Hodges, R. (2015). *Academic transformation: The road to college success.* (3rd ed.). Boston, MA: Pearson.

Assessed Learning Objectives

1.1 Determine the number of significant digits that should be recorded in a measurement when given the measuring tool.
1.2. Convert from one temperature scale to another.

2.1. Determine which zeros in a recorded measurement are significant.
2.2. Express the values of measurements and calculations using the correct number of significant digits.
2.3 Convert numbers between standard notation and scientific notation.

3.1. Convert metric system measurements into related units.
3.2. Generate conversion factors from equivalencies that are used for unit conversion and dimensional analysis.
3.3. Report all measurements and calculated values so that each number reported contains *magnitude*, *uncertainty*, and *units*.
3.4. Use GFPSR to solve mathematical problems.

4.1. Determine the number of atoms in a molecule or compound by reading a chemical formula.
4.2. Classify matter as a pure substance or a mixture.
4.3. Classify pure substances as elements or compounds.
4.4. Correlate particle motion with the different states of matter and its relationship to kinetic energy.
4.5. Understand all phase change processes and their energy requirements.
4.6. Predict how the density of a substance changes with external heating/cooling.

5.1. Know that specific heat of a substance is an intrinsic property of all matter and changes when the state of matter changes.
5.2. Understand how heat capacity is related to the specific heat of a substance and the factors that influence both.
5.3. Interpret a heating/cooling curve and describe how it relates to specific heat.
5.4. Solve mathematical problems involving specific heat and heat capacity.

6.1. Determine the number of protons and neutrons in an atom based on the atomic symbol.
6.2. Describe the similarities and differences between isotopes and the parent atom.
6.3. Understand how an ion is formed and how it differs from the neutral, parent atom.
6.4. Use the terms cation and anion when describing ions generated from metals and non-metals, respectively.

7.1. Analyze how a heating/cooling curve graph displays the phase changes of matter.

8.1. Rank sets of charged particles in order of increasing force of attraction by analyzing distances between particles and the total charges involved.
8.2. Predict the changes to the attractive force on the outermost electron in an atom as you move down or across the periodic table.

9.1. Draw a ground state orbital diagram for each of the first 18 elements using the Aufbau principle, Pauli exclusion principle, and Hund's rule.
9.2. Write a ground state electron configuration for each of the first 18 elements.
9.3. Determine if a ground state orbital diagram is drawn correctly.

10.1. Predict the ground state electron configuration for an atom of any element using only the periodic table as a guide.

11.1. Identify different properties that can be used to classify elements as metals and nonmetals.
11.2. Test and analyze the data to determine if a given element is a metal or a nonmetal.
11.3. Understand the difference between chemical and physical properties and identify examples of each.

12.1. Identify compounds containing metals that are able to form multiple ions.
12.2. Name simple binary ionic compounds using the Stock system of naming.

13.1. Describe polyatomic ions as a group of atoms with a net charge.
13.2. Identify common polyatomic ions, both by name and chemical formula.
13.3. Name ternary ionic compounds and write the chemical formulas for them.

14.1. Name binary molecular compounds based on their chemical formulas.
14.2. Write chemical formulas for binary molecular compounds based on their names.
14.3. Distinguish binary molecular compounds from other types of compounds, such as ionic compounds or more complex molecular compounds.

	Learning Objectives									
	1.1	1.2	2.1	2.2	2.3	3.1	3.2	3.3	3.4	4.1
Questions Aligned with Learning Objectives	59		32 49	62	64		50 51		SA 4	30
Number of Questions Answered Incorrectly										

	Learning Objectives									
	4.2	4.3	4.4	4.5	4.6	5.1	5.2	5.3	5.4	6.1
Questions Aligned with Learning Objectives	34	31 33 35 37 39 44	36 53 57 63	52	4 61 66			54 55		7 10 12 71 SA 5a
Number of Questions Answered Incorrectly										

	Learning Objectives									
	6.2	6.3	6.4	7.1	8.1	8.2	9.1	9.2	9.3	10.1
Questions Aligned with Learning Objectives	9 11 13 60	8 14 47 56 SA 3 SA 6a, 6b	19 58 SA 6c		1 23	15 24 43	3 SA 2	18 46 73 74 SA 5b	2 17 SA 5c	25 48
Number of Questions Answered Incorrectly										

	Learning Objectives									
	11.1	11.2	11.3	12.1	12.2	13.1	13.2	13.3	14.1	14.2
Questions Aligned with Learning Objectives	6 16 22	21 65	67 68 69 70	20 40 SA 1c, 1e	45 SA 1b, 1f	38 42	5 72	28 SA 1d	29 41 SA 1a	SA 1g
Number of Questions Answered Incorrectly										

	Learning Objectives									
	14.3									
Questions Aligned with Learning Objectives	26 27									
Number of Questions Answered Incorrectly										

Bloom's Taxonomy, Learning Objectives, and Study Strategies

Bloom's Level of Mastery	**Learning Objectives**	**Study Strategies**
Remembering	2.1, 3.3, 4.1, 5.1, 6.1, 11.1, 12.1, 12.2, 12.3, 12.4, 12.5, 13.1	Identify chemical objects or components from flash cards; self-testing; draw, classify, select, or match items; write out the textbook definitions
Understanding	1.1, 2.2, 4.2, 4.3, 4.4, 4.5, 5.2, 6.2, 6.3, 8.1, 13.3, 14.1, 14.2	Describe a process in your own words; provide examples of a process; write a sentence utilizing vocabulary; peer vocabulary quizzes; define components and variables of a given equation
Applying	1.2, 2.3, 3.1, 3.2, 3.4, 4.6, 5.3, 5.4, 6.4, 8.2, 9.1, 9.2, 10.1, 12.6, 13.2	Review a process and describe what would happen if you alter the activity of a component in the system; peer-teach; peer critique of content presentation; discuss a real-world example of a concept covered in class; solve practice word problems using GFPSR problem-solving method
Analyzing	7.1, 9.3, 11.2	Compare and contrast two ideas or concepts; create a map of the main concepts by defining the relationships of the concepts using one- or two-way arrows
Evaluating		
Creating		

Module 3a: Chemistry II Midterm Examination

Pre-Plan: Gather information about the exam	
	Chemistry
When and where is the exam? How much time do I have to take it?	
How much is the exam worth (% of final grade)?	
Identify: • Types of questions on exam • Expected level of learning • Number of each type and point value	
Identify material (i.e., topics, sections) exam will cover and where you will find it (e.g., text, notes, quizzes).	
How do you think you will perform on the exam (percentage)? *to be completed the night before the exam	
How do you think you performed on the exam (percentage)? *to be completed immediately following the exam	

List Strategies and Activate Plan		
Date	**<u>Learning Strategies</u>:** How, when where, and with whom will you study?	**Done**

Take Exam

Evaluate Plan Using Feedback: Exam Wrapper			
Directions: Evaluate your exam preparation habits and performance according to the following statements.			
Exam Grade: _______ Overall Grade: _______	Great job!	Not too bad	Needs work
Completed homework consistently.			
Consistently checked quality of homework for proficiency.			
Displayed active involvement in class (paid attention, engaged in group work/POGIL activities, asked questions).			
Created clear, detailed notes that addressed lesson objectives (ALOs).			
Completed practice problems associated with the lesson objectives.			
Regularly reviewed material throughout the quarter.			
Studied the appropriate material for the exam.			
Used study methods appropriate to the exam.			
Understood how to use and utilized the Chemistry Reference Data Card (RDC).			
Self-regulated my study environment.			
Got help if I needed it (AI, peers, SOS, etc.).			
Spent enough time studying.			
Distributed study time instead of cramming.			
Predicted exam questions.			
Felt confident going into the exam.			
Understood the exam directions.			
Felt confident during the exam.			
Reviewed the exam before turning it in.			
Felt confident after completing the exam.			

1. What part of your preparation (strategies) helped you **most** on the exam?

2. What part of your preparation (strategies) helped you **least** on the exam?

3. How will you improve upon your preparation and/or engagement during the second half of the quarter? Highlight areas that you identified as “needs work.” Be specific: the strategies you use should be linked to the mastery level assessed by each question. Refer to the learning objective map on the next pages and the Bloom’s Taxonomy table on to help.

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Nist, S. & Simpson, M. (1989). PLAE. A validated study strategy. *Journal of Reading, 33,* 182-186.
Seller, D., Dochen, C., & Hodges, R. (2015). *Academic transformation: The road to college success.* (3rd ed.). Boston, MA: Pearson.

Assessed Learning Objectives

15.1. Translate word equations describing a chemical reaction into a formula equation using accurate chemical formulas and symbols.
15.2. Apply the law of Conservation of Mass and the RAP method to systematically balance chemical equations where coefficients are expressed with the smallest set of whole numbers.

16.1. Generate mole ration conversion factors between two species in a balanced equation.
16.2. Understand how to generate all conversion factors found on the Mole Map.
16.3. Use the Mole Map to convert between moles, mass, volume, and number of particles of one substance.
16.4. Use the Mole Map to convert between moles, mass, volume, and number of particles between any two substances in a balanced equation.
16.5. Use the concept of stoichiometry to predict the quantity of one substance from a given quantity of another.

17.1. Determine the appropriate amounts of compounds to mix together to exactly use them up in a reaction.

18.1. Identify the limiting reactant and excess reactant in a given situation.
18.2. Calculate the maximum amount of product formed (moles, grams) and the amount of excess reactant remaining in a limiting reactant problem.

19.1. Categorize reactions as synthesis, decomposition, single replacement, double replacement, or combustion when given a complete chemical reaction.
19.2. Using one of the reaction categories, predict the products of a chemical reaction accurately when given the reactants.

20.1. Determine if two gas variables have a direct or inverse proportional relationship based on given data.
20.2. Explain the relationships among gas variables on a molecular level by describing changes in how hard and how often molecules are hitting.
20.3. Understand the effect of gas variables (temperature, moles, volume) on gases and why gases exhibit pressure (in a closed container).
20.4. Understand the Combined (Common) Gas Law and Ideal Gas Law and be able to solve related problems mathematically.
20.5. Identify and understand the relationship between variables in Charles', Boyle's, and Gay-Lussac's Laws.

21.1. Evaluate how we can determine if a chemical change has occurred (i.e. a chemical reaction has taken place).
21.2. Differentiate and list the differences between physical and chemical changes.

	Learning Objectives									
	15.1	15.2	16.1	16.2	16.3	16.4	16.5	17.1	18.1	18.2
Questions Aligned with Learning Objectives	9 34	1 2 3 4 5 6 SA 1a	28	30	7 11 SA 1b SA 2	8 12	10 SA 3b	29	14 15 16 17 SA 4a	13 SA 4b
Number of Questions Answered Incorrectly										

	Learning Objectives									
	19.1	19.2	20.1	20.2	20.3	20.4	20.5	21.1	21.2	
Questions Aligned with Learning Objectives	18 19 20 21 SA 3a	22 23 24	33	35	31 32	36 37 38	40	39	25 26 27	
Number of Questions Answered Incorrectly										

Bloom's Taxonomy, Learning Objectives, and Study Strategies

Bloom's Level of Mastery	Learning Objectives	Study Strategies
Remembering	18.1, 20.1, 20.5	Identify chemical objects or components from flash cards; self-testing; draw, classify, select, or match items; write out the textbook definitions
Understanding	16.2, 19.1, 20.2, 20.3, 20.4, 21.2	Describe a process in your own words; provide examples of a process; write a sentence utilizing vocabulary; peer vocabulary quizzes; define components and variables of a given equation
Applying	15.1, 16.3, 16.4, 16.5, 18.2, 19.2	Review a process and describe what would happen if you alter the activity of a component in the system; peer-teach; peer critique of content presentation; discuss a real-world example of a concept covered in class; solve practice word problems using GFPSR problem-solving method
Analyzing	17.1, 15.1	Compare and contrast two ideas or concepts; create a map of the main concepts by defining the relationships of the concepts using one- or two-way arrows
Evaluating	21.1	Evaluate data from an experiment and describe what it identifies
Creating	16.1	Self-testing

Module 3b: Chemistry II Final Examination

Pre-Plan: Gather information about the exam	
	Chemistry
When and where is the exam? How much time do I have to take it?	
How much is the exam worth (% of final grade)?	
Identify: • Types of questions on exam • Expected level of learning • Number of each type and point value	
Identify material (i.e., topics, sections) exam will cover and where you will find it (e.g., text, notes, quizzes).	
How do you think you will perform on the exam (percentage)? *to be completed the night before the exam	
How do you think you performed on the exam (percentage)? *to be completed immediately following the exam	

List Strategies and Activate Plan		
Date	**<u>Learning Strategies</u>:** How, when where, and with whom will you study?	**Done**

Take Exam

Evaluate Plan Using Feedback: Exam Wrapper			
Directions: Evaluate your exam preparation habits and performance according to the following statements.			
Exam Grade: _______ Overall Grade: _______	Great job!	Not too bad	Needs work
Completed homework consistently.			
Consistently checked quality of homework for proficiency.			
Displayed active involvement in class (paid attention, engaged in group work/POGIL activities, asked questions).			
Created clear, detailed notes that addressed lesson objectives (ALOs).			
Completed practice problems associated with the lesson objectives.			
Regularly reviewed material throughout the quarter.			
Studied the appropriate material for the exam.			
Used study methods appropriate to the exam.			
Understood how to use and utilized the Chemistry Reference Data Card (RDC).			
Self-regulated my study environment.			
Got help if I needed it (AI, peers, SOS, etc.).			
Spent enough time studying.			
Distributed study time instead of cramming.			
Predicted exam questions.			
Felt confident going into the exam.			
Understood the exam directions.			
Felt confident during the exam.			
Reviewed the exam before turning it in.			
Felt confident after completing the exam.			

1. What part of your preparation (strategies) helped you **most** on the exam?

2. What part of your preparation (strategies) helped you **least** on the exam?

3. What changes did you make to test preparation strategies and how did the changes that you made to your test preparation from the midterm examination to the final examination benefit or hinder your performance? Did you align your preparation strategies to the learning objectives?

Adapted from:
Nist, S. & Simpson, M. (1989). PLAE. A validated study strategy. *Journal of Reading, 33,* 182-186.
Seller, D., Dochen, C., & Hodges, R. (2015). *Academic transformation: The road to college success.* (3rd ed.). Boston, MA: Pearson.

Assessed Learning Objectives

15.1. Translate word equations describing a chemical reaction into a formula equation using accurate chemical formulas and symbols.
15.2. Apply the law of Conservation of Mass and the RAP method to systematically balance chemical equations where coefficients are expressed with the smallest set of whole numbers.

16.1. Generate mole ration conversion factors between two species in a balanced equation.
16.2. Understand how to generate all conversion factors found on the Mole Map.
16.3. Use the Mole Map to convert between moles, mass, volume, and number of particles of one substance.
16.4. Use the Mole Map to convert between moles, mass, volume, and number of particles between any two substances in a balanced equation.
16.5. Use the concept of stoichiometry to predict the quantity of one substance from a given quantity of another.

17.1. Determine the appropriate amounts of compounds to mix together to exactly use them up in a reaction.

18.1. Identify the limiting reactant and excess reactant in a given situation.
18.2. Calculate the maximum amount of product formed (moles, grams) and the amount of excess reactant remaining in a limiting reactant problem.

19.1. Categorize reactions as synthesis, decomposition, single replacement, double replacement, or combustion when given a complete chemical reaction.
19.2. Using one of the reaction categories, predict the products of a chemical reaction accurately when given the reactants.

20.1. Determine if two gas variables have a direct or inverse proportional relationship based on given data.
20.2. Explain the relationships among gas variables on a molecular level by describing changes in how hard and how often molecules are hitting.
20.3. Understand the effect of gas variables (temperature, moles, volume) on gases and why gases exhibit pressure (in a closed container).
20.4. Understand the Combined (Common) Gas Law and Ideal Gas Law and be able to solve related problems mathematically.
20.5. Identify and understand the relationship between variables in Charles', Boyle's, and Gay-Lussac's Laws.

21.1. Evaluate how we can determine if a chemical change has occurred (i.e. a chemical reaction has taken place).
21.2. Differentiate and list the differences between physical and chemical changes.

22.1. Understand and differentiate between terms listed in ‘definitions’ section.
22.2. Distinguish between saturated and unsaturated solutions by examining particulate models, mathematical data, and graphs.
22.3. Calculate the solubility of a substance in water from mass of a solute and solvent data.
22.4. Determine mass of solute needed to reach saturation or the amount of solid that would precipitate from solution given appropriate data.

23.1. Construct and interpret a solubility curve.
23.2. Use solubility curves to distinguish among saturated, unsaturated, and supersaturated solutions.
23.3. Explain how temperature influences the solubility of a solid substance.

24.1. Identify solutions as dilute or concentrated when given two solutions to compare.
24.2. Express molarity as a value based on the ratio of moles of solute to liters of solution.
24.3. Calculate molarity when given the amount of solute in moles or grams and the volume of solution.

25.1. Describe how the initial number of reactant and product particles change over time as a reversible reaction establishes equilibrium.
25.2. Identify the point in time where equilibrium in a system begins given tabular or graphical data.
25.3. Identify factors that disrupt or stress a system already in equilibrium (LeChatelier’s principle) and predict the behavior of the system when reestablishing equilibrium.
25.4. Predict if a reaction is reactant-favored or product-favored based on relative reaction rates of reactant and product, the ratio of product and reactant concentrations at equilibrium or by using the ICE method given appropriate parameters.
25.5 Predict the value of equilibrium constant value based on relative rates of the forward and reverse reactions or final equilibrium concentrations, not initial concentration conditions.

26.1. Describe the physical and chemical properties of acids and bases.
26.2. Describe and understand similarities and differences between Arrhenius and Bronsted-Lowry acids and bases.
26.3. Describe the role of an acid or base in a reaction as either a hydrogen ion donator or a hydrogen ion accepter.
26.4. Identify acid-base conjugate pairs in a reaction.
26.5. Predict the correct products in acid/base neutralization reactions.

27.1. Describe what happens at the particulate level that makes a strong acid different from a weak acid.
27.2. Relate solution conductivity to the strength of an acid.
27.3. Appropriately describe an acid solution using the terms concentrated or dilute and weak or strong.
27.4. Write acid dissociation reactions in water and properly express its k_a value.

28.1. Calculate hydronium and hydroxide ion concentrations for a solution given either value.
28.2. Calculate the pH or pOH of a solution given the hydronium ion or hydroxide ion concentration.
28.3. Relate hydronium or hydroxide ion concentration and pH to the acidity, basicity, or neutrality of a solution.

	Learning Objectives									
	15.1	15.2	16.1	16.2	16.3	16.4	16.5	17.1	18.1	18.2
Questions Aligned with Learning Objectives		33 42			SA 8a	30 37	34 36 SA 6a SA 6b		41 43 SA 6c	SA 6d SA 6e
Number of Questions Answered Incorrectly										

	Learning Objectives									
	19.1	19.2	20.1	20.2	20.3	20.4	20.5	21.1	21.2	22.1
Questions Aligned with Learning Objectives	38 39 40	29 35		59	31	55 56 SA 8b				3
Number of Questions Answered Incorrectly										

	Learning Objectives									
	22.2	22.3	22.4	23.1	23.2	23.3	24.1	24.2	24.3	25.1
Questions Aligned with Learning Objectives	1 2 5	4	62 2		60 61	6	7	10 11 12	8 9 SA 3	13 15 58
Number of Questions Answered Incorrectly										

	Learning Objectives									
	25.2	25.3	25.4	25.5	26.1	26.2	26.3	26.4	26.5	27.1
Questions Aligned with Learning Objectives		32 57	16	14		17 18	47 48	21 22 49 50	19 SA 4a SA 5	20
Number of Questions Answered Incorrectly										

	Learning Objectives									
	27.2	27.3	27.4	28.1	28.2	28.3				Chem. I
Questions Aligned with Learning Objectives	23 24		25 SA 4b SA 4c	SA 1a	28 SA 1b	26 27 SA 1c				44 45 46 51 52 53 SA 7
Number of Questions Answered Incorrectly										

Bloom's Taxonomy, Learning Objectives, and Study Strategies

Bloom's Level of Mastery	Learning Objectives	Study Strategies
Remembering	18.1, 20.1, 20.5, 24.1, 26.1, 26.2, 26.3, 26.4	Identify chemical objects or components from flash cards; self-testing; draw, classify, select, or match items; write out the textbook definitions
Understanding	16.2, 19.1, 20.2, 20.3, 20.4, 21.2, 22.1, 22.2, 23.2, 23.3, 24.2, 25.1, 25.2, 25.3, 27.1, 27.3, 27.4	Describe a process in your own words; provide examples of a process; write a sentence utilizing vocabulary; peer vocabulary quizzes; define components and variables of a given equation
Applying	15.1, 16.3, 16.4, 16.5, 18.2, 19.2, 22.3, 22.4, 23.1, 24.3, 25.4, 25.5, 26.5, 27.2, 28.1, 28.2, 28.3	Review a process and describe what would happen if you alter the activity of a component in the system; peer-teach; peer critique of content presentation; discuss a real-world example of a concept covered in class; solve practice word problems using GFPSR problem-solving method
Analyzing	17.1, 15.1	Compare and contrast two ideas or concepts; create a map of the main concepts by defining the relationships of the concepts using one- or two-way arrows
Evaluating	21.1	Evaluate data from an experiment and describe what it identifies
Creating	16.1	Self-testing

Module 4: Physics

Physics courses in high schools are taken by the top 25% of students nationally (National Science Foundation, 1993) and such students represent future science educators, engineers, and physicists (Sadler & Tai, 2000). However, remarkably unique to the school in this work is that students, regardless of academic major, are enrolled in an introductory physics course. The Physics 100 course is a traditional algebra-based introductory college physics course that provides students with the opportunity to learn fundamental physics principles and complex problem-solving skills needed for more advanced study. Post-secondary physics instruction relies on what prior knowledge students bring to the course (National Research Council, 2000), so low high school physics enrollment does not bode well for success in college physics courses.

Physics can be characterized by iterative problem solving and as such, students are successful in physics courses if they can utilize information recall strategies and if the students can adapt to new scenarios (Finegold & Mass, 1985). In the following exam wrapper, repeated problem-solving has been identified as a key factor for success in physics. Student success is also hinged on the ability to understand and utilize the physics formula sheet in the Physics 100 course. Students are given a list of all of the formulas that they have utilized throughout the course and are able to refer to the formula sheet during their assessments. The formula sheet does not define variables nor does it have rearranged equations to isolate variables. Therefore, students will be more successful on exams if they know how to read and understand the formula sheet as well as if they know how to use the formulas on the formula sheet—again, through repeated practice. In this way, physics is very similar to chemistry in that rote memorization tasks have been eliminated in favor of broad conceptual understandings of the content. Because chemistry and physics are similar in the skills required to be successful, the study strategies for the two courses are inherently similar, as well.

Module 4a: Physics Midterm Examination

Pre-Plan: Gather information about the exam	
	Physics
When and where is the exam? How much time do I have to take it?	
How much is the exam worth (% of final grade)?	
Identify: • Types of questions on exam • Expected level of learning • Number of each type and point value	
Identify material (i.e., topics, sections) exam will cover and where you will find it (e.g., text, notes, quizzes).	
How do you think you will perform on the exam (percentage)? *to be completed the night before the exam	
How do you think you performed on the exam (percentage)? *to be completed immediately following the exam	

List Strategies and Activate Plan		
Date	**<u>Learning Strategies</u>:** How, when where, and with whom will you study?	**Done**

Take Exam

Evaluate Plan Using Feedback: Exam Wrapper			
Directions: Evaluate your exam preparation habits and performance according to the following statements.			
Exam Grade: _______ Overall Grade: _______	Great job!	Not too bad	Needs work
Completed homework consistently.			
Consistently checked quality of homework for proficiency.			
Displayed active involvement in class (paid attention, engaged in group work/POGIL activities, asked questions).			
Created clear, detailed notes that addressed lesson objectives (ALOs).			
Completed practice problems associated with the lesson objectives.			
Regularly reviewed material throughout the quarter.			
Studied the appropriate material for the exam.			
Used study methods appropriate to the exam.			
Understood how to use and utilized the Physics formula sheet.			
Self-regulated my study environment.			
Got help if I needed it (AI, peers, SOS, etc.).			
Spent enough time studying.			
Distributed study time instead of cramming.			
Predicted exam questions.			
Felt confident going into the exam.			
Understood the exam directions.			
Felt confident during the exam.			
Reviewed the exam before turning it in.			
Felt confident after completing the exam.			

1. What part of your preparation (strategies) helped you **most** on the exam?

2. What part of your preparation (strategies) helped you **least** on the exam?

3. How will you improve upon your preparation and/or engagement during the second half of the quarter? Highlight areas that you identified as "needs work." Be specific: the strategies you use should be linked to the mastery level assessed by each question. Refer to the learning objective map on the next pages and the Bloom's Taxonomy table on to help.

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Seller, D., Dochen, C., & Hodges, R. (2015). *Academic transformation: The road to college success.* (3rd ed.). Boston, MA: Pearson.

Assessed Learning Objectives

1.1. Differentiate between a scalar and vector quantity.
1.2. Calculate component and resultant vectors using graphical vector addition.
1.3. Use trigonometry to calculate the angles and/or sides of a right triangle.

2.1. Identify the differences between distance and displacement.
2.2. Identify the differences between speed and velocity.
2.3. Calculate the distance and displacement of an object.
2.4. Calculate the speed and velocity of an object.

3.1. Calculate the displacement, velocity, and travel time of an object experiencing acceleration.
3.2. Calculate acceleration given the displacement, travel time, and/or velocities of an object.
3.3. Calculate the height and velocity of an object in free fall.

4.1. Draw, read, and/or interpret velocity graphs (displacement vs. time).
4.2. Draw, read, and/or interpret acceleration graphs (velocity vs. time).

5.1. Understand, apply, and explain Newton's 1st Law of Motion.
5.2. Understand, apply, and explain Newton's 2nd Law of Motion.

6.1. Understand, apply, and explain Newton's 3rd Law of Motion.
6.2. Combine the concepts of Newton's 3rd Law with acceleration, velocity, displacement, and time.
6.3. Identify the relationship between unbalanced forces and acceleration.

7.1. Use displacement and time measurements to calculate average velocity.
7.2. Generate velocity and acceleration graphs from motion data.
7.3. Interpolate and extrapolate from measured data.

	Learning Objectives									
	1.1	1.2	1.3	2.1	2.2	2.3	2.4	3.1	3.2	3.3
Questions Aligned with Learning Objectives	7 13	11 SA 4	10 16 20		27	8 17	1 2	9 SA 1 SA 2 SA 7	SA 5a	5 15 29 SA 8
Number of Questions Answered Incorrectly										

	Learning Objectives									
	4.1	4.2	5.1	5.2	6.1	6.2	6.3	7.1	7.2	7.3
Questions Aligned with Learning Objectives	30 SA 6a,b,c,d	23 SA 6e,f	4	6 12 14 19 21 SA 5b	SA 3	28	22	3 18 26	24 SA 6h	25 SA 6g
Number of Questions Answered Incorrectly										

Bloom's Taxonomy, Learning Objectives, and Study Strategies

Bloom's Level of Mastery	**Learning Objectives**	**Study Strategies**
Remembering	2.1, 2.2, 6.3	Self-testing; draw, classify, select, or match items; write out the textbook definitions
Understanding	1.1, 5.1, 5.2, 6.1	Describe a process in your own words; provide examples of a process; write a sentence utilizing vocabulary; peer vocabulary quizzes; define components and variables of a given equation; solve practice problems
Applying	1.2, 1.3, 2.3, 2.4, 3.1, 3.2, 3.3, 4.1, 4.2, 6.2, 7.1	Review a process and describe what would happen if you modify one variable in the system; peer-teach; peer critique of content presentation
Analyzing	7.3	Rearrange formulas and equations in terms of new variables; describe how laws or theorems relate to the natural world
Evaluating		
Creating	7.2	Develop your own practice problems

Module 4b: Physics Final Examination

Pre-Plan: Gather information about the exam	
	Physics
When and where is the exam? How much time do I have to take it?	
How much is the exam worth (% of final grade)?	
Identify: • Types of questions on exam • Expected level of learning • Number of each type and point value	
Identify material (i.e., topics, sections) exam will cover and where you will find it (e.g., text, notes, quizzes).	
How do you think you will perform on the exam (percentage)? *to be completed the night before the exam	
How do you think you performed on the exam (percentage)? *to be completed immediately following the exam	

List Strategies and Activate Plan		
Date	**Learning Strategies:** How, when where, and with whom will you study?	**Done**

Take Exam

Evaluate Plan Using Feedback: Exam Wrapper			
Directions: Evaluate your exam preparation habits and performance according to the following statements.			
Exam Grade: _______ Overall Grade: _______	Great job!	Not too bad	Needs work
Completed homework consistently.			
Consistently checked quality of homework for proficiency.			
Displayed active involvement in class (paid attention, engaged in group work/POGIL activities, asked questions).			
Created clear, detailed notes that addressed lesson objectives (ALOs).			
Completed practice problems associated with the lesson objectives.			
Regularly reviewed material throughout the quarter.			
Studied the appropriate material for the exam.			
Used study methods appropriate to the exam.			
Understood how to use and utilized the Physics formula sheet.			
Self-regulated my study environment.			
Got help if I needed it (AI, peers, SOS, etc.).			
Spent enough time studying.			
Distributed study time instead of cramming.			
Predicted exam questions.			
Felt confident going into the exam.			
Understood the exam directions.			
Felt confident during the exam.			
Reviewed the exam before turning it in.			
Felt confident after completing the exam.			

1. What part of your preparation (strategies) helped you **most** on the exam?

2. What part of your preparation (strategies) helped you **least** on the exam?

3. What changes did you make to test preparation strategies and how did the changes that you made to your test preparation from the midterm examination to the final examination benefit or hinder your performance? Did you align your preparation strategies to the learning objectives?

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Assessed Learning Objectives

1.1. Differentiate between a scalar and vector quantity.
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2.1. Identify the differences between distance and displacement.
2.2. Identify the differences between speed and velocity.
2.3. Calculate the distance and displacement of an object.
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3.1. Calculate the displacement, velocity, and travel time of an object experiencing acceleration.
3.2. Calculate acceleration given the displacement, travel time, and/or velocities of an object.
3.3. Calculate the height and velocity of an object in free fall.

4.1. Draw, read, and/or interpret velocity graphs (displacement vs. time).
4.2. Draw, read, and/or interpret acceleration graphs (velocity vs. time).

5.1. Understand, apply, and explain Newton's 1^{st} Law of Motion.
5.2. Understand, apply, and explain Newton's 2^{nd} Law of Motion.

6.1. Understand, apply, and explain Newton's 3^{rd} Law of Motion.
6.2. Combine the concepts of Newton's 3^{rd} Law with acceleration, velocity, displacement, and time.
6.3. Identify the relationship between unbalanced forces and acceleration.

7.1. Use displacement and time measurements to calculate average velocity.
7.2. Generate velocity and acceleration graphs from motion data.
7.3. Interpolate and extrapolate from measured data.

8.1. Apply Newton's 2^{nd} Law to determine frictional force, acceleration, or weight of an object.
8.2. Differentiate between frictional force, applied force, and net force.
8.3. Calculate frictional force, applied force, and net force given variables such as mass, weight, and force(s).

9.1. Differentiate between static and kinetic friction.
9.2. Identify and solve problems involving a coefficient of friction.
9.3. Construct the Normal force vector and calculate its magnitude and direction on both a flat and inclined surface.
9.4. Draw a free body diagram to depict and solve problems.

10.1. Understand and perform calculations involving the two-dimensional components of motion.

11.1. Apply the laws and components of motion to projectiles.
11.2. Understand and perform calculations involving projectile motion.

12.1. Apply Newton's 1st Law of Motion to the impulse-momentum theorem.
12.2. Understand the relationship between Newton's 2nd Law of Motion and conservation of momentum.

13.1. Differentiate between elastic and inelastic collisions.
13.2. Use the law of conservation of momentum to solve collision problems mathematically.

14.1. Utilize the two-dimensional components of motion to launch a projectile on target.

	Learning Objectives									
	1.1	1.2	1.3	2.1	2.2	2.3	2.4	3.1	3.2	3.3
Questions Aligned with Learning Objectives	11	4 19						18	33	
Number of Questions Answered Incorrectly										

	Learning Objectives									
	4.1	4.2	5.1	5.2	6.1	6.2	6.3	7.1	7.2	7.3
Questions Aligned with Learning Objectives	34		26	36 SA 6b	35	10	9 25 27			
Number of Questions Answered Incorrectly										

	Learning Objectives									
	8.1	8.2	8.3	9.1	9.2	9.3	9.4	10.1	11.1	11.2
Questions Aligned with Learning Objectives	2 3 38		SA 6e	5 31 SA 3a	28 32	6 7 SA 6c	12 30 39 SA 1a SA 2a SA 6a,d	1 20 SA 1b,c SA 2b,c	14 23 24 37	8 SA 5
Number of Questions Answered Incorrectly										

	Learning Objectives									
	12.1	12.2	13.1	13.2	14.1					
Questions Aligned with Learning Objectives	13 21 SA 4a,b	16 29 SA 3b	17 SA 4d	15 22 SA 3c SA 4c						
Number of Questions Answered Incorrectly										

Bloom's Taxonomy, Learning Objectives, and Study Strategies

Bloom's Level of Mastery	**Learning Objectives**	**Study Strategies**
Remembering	2.1, 2.2, 6.3, 9.4	Self-testing; draw, classify, select, or match items; write out the textbook definitions
Understanding	1.1, 5.1, 5.2, 6.1, 8.2, 9.1, 12.2, 13.1	Describe a process in your own words; provide examples of a process; write a sentence utilizing vocabulary; peer vocabulary quizzes; define components and variables of a given equation
Applying	1.2, 1.3, 2.3, 2.4, 3.1, 3.2, 3.3, 4.1, 4.2, 6.2, 7.1, 8.1, 8.3, 9.2, 9.3, 10.1, 11.1, 11.2, 12.1, 13.2, 14.1	Review a process and describe what would happen if you modify one variable in the system; peer-teach; peer critique of content presentation
Analyzing	7.3	Rearrange formulas and equations in terms of new variables; describe how laws or theorems relate to the natural world
Evaluating		
Creating	7.2	Develop your own practice problems

Chapter Four: Conclusions and Recommendations

The scaffolded exam wrapper strategy makes a few assumptions that should be noted. First and foremost, the strategy assumes that an instructor has diligently assessed his examinations and ensured that each question accurately reflects the course learning objectives. Without test questions that are linked to learning objectives, an instructor cannot ensure that he is providing the appropriate test preparation strategies for his students and instead, he is likely to provide general strategies that may or may not be the most effective. It may seem intuitive for an instructor to develop test questions that directly reflect lesson objectives but it is likely rare that an instructor analyzes his exams and maps each question to the objective that is assessed. Mapping exam questions to learning objectives and providing study strategies that appropriately support learning objectives is a time-consuming process. However, instructors likely do not change their exams from semester to semester so the effort required to start utilizing the scaffolded exam wrapper will be large but there will be a rapid decline in the effort requirements after the first iteration.

The second assumption this strategy rests upon is that the instructor utilizing the scaffolded exam wrapper has relatively small classes. The strategy only works if an instructor can provide one-on-one support and hold his students accountable. Although an instructor could utilize the scaffolded exam wrapper strategy with large lecture classes, the strategy is really designed for professors to provide feedback to students and as such the strategy can be used as a counseling tool to address why students may be struggling in class. Exam wrappers have only been shown to improve students' assessment performances in small courses (Gezer-Templeton et al., 2017; Metzger et al., 2018; Soicher & Gurung, 2017), and have not been utilized in large introductory lecture courses.

Finally, the scaffolded exam wrapper strategy assumes that students will engage with the strategy beyond when the strategy is introduced. Research has continuously proven that student engagement is key critical to achievement and learning (Kahu, 2013; Trowler & Trowler, 2010), and student-centered learning strategies, in particular, require student engagement to be successful. However, some students may not feel that they need the scaffolded exam wrapper strategy. Research shows that students fail to implement new study strategies when needed (Broekkamp & Van Hout-Wolters, 2007) and utilize strategies that the students believed helped them succeed in high school (Ruban & Reis, 2006). The scaffolded exam wrapper strategy likely works best with students who are impressionable and students who struggle academically.

Although the scaffolded exam wrapper strategy is designed here for science classes, that doesn't mean that it cannot be implemented into other subject areas. Test preparation strategies transcend content areas and curricula and are exceptionally useful to first-year college students who struggle to transition from high school to post-secondary learning environments. Instructors need to be willing to make changes to their long-standing beliefs about education and utilize recommendations from educational literature. Far too often are professors [and universities] concerned more with research than with teaching (Prince, Felder, & Brent, 2007); it is time for educators to appreciate what the literature has to offer.

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