Open-ended responses

Answer the following questions

- I have participated in PLTL during the previous semester (y/n)
  - If yes, then please respond to the following statement to the best of your ability
    - Compared to last semester, describe any differences you feel writing reflections had on your PLTL experience.
- Describe any benefits you feel you experienced because of completing reflections.
- How, if at all, did the reflections contribute to your learning of CHEM 1312 concepts?
- What did you learn about yourself from completing the reflections?
- Please share any additional thoughts about the PLTL reflections.

Coaching to Learn: Motivating Students to Adopt and Adapt Effective Learning Strategies

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Abstract

Abundant laboratory and classroom research demonstrate the superior effectiveness of effortful learning strategies based on cognitive science over re-reading, highlighting, and other strategies more widely used by college students. However, persuading

students to adopt and adhere to effective strategies is difficult. This article outlines a novel, peer-to-peer intervention rooted in the Knowledge, Belief, Commitment, and Planning theoretical framework (McDaniel & Einstein, 2020) that emphasizes the need for students to believe in, commit to, and plan to use effective strategies rather than simply "know" them. Opportunities for faculty and learning center personnel to incorporate elements of the intervention into existing programming and adapt them to local institutional needs are described.

Keywords: training learning strategies, peer-to-peer strategy intervention, effective learning strategies, cognitive science, metacognition, motivation, desirable difficulties

Coaching to Learn: Motivating Students to Adopt and Adapt Effective Learning Strategies

Abundant research in laboratory settings and classrooms demonstrates the superior effectiveness of learning strategies based on cognitive science compared with passive techniques more often used by college students, such as re-reading, highlighting, or reviewing problems alongside step-by-step solutions (Dunlosky et al., 2013; Fiorella & Mayer, 2015; Pashler et al., 2007). Far less is known about how to motivate and train students to use research-based study strategies independently

and apply them across varied subject matter and courses (McDaniel & Einstein, 2020). This knowledge gap creates an opportunity for learning centers to build on their long history of innovation in helping students succeed academically (Arendale, 2004).

Equipping students with the learning strategies they need to succeed in college and in the fast-changing labor market they encounter after graduation is one of the most effective means of demonstrating the value of higher education. This effort is especially important now as higher education faces criticism on multiple political fronts (e.g. Confessore, 2023), polls track weakening public confidence in the value of college (Belkin, 2023), and artificial intelligence changes the work college graduates perform (Di Battista et al. 2023). Although many studies focus on learning strategies in the context of particular academic subjects, such as reading and mathematics (Donker et al., 2014), effective learning strategies are not discipline-specific. Indeed, students who employ discipline-independent strategies effectively are expected to learn better across subject matter and courses (e.g., Bernacki et al., 2016; Cogliano et al., 2021). Thus, scaffolding college students' development of skill in employing effective learning strategies has potential to improve performance for all students and merits consideration among the suite of offerings more typically included within learning center academic coaching programs, such as time management and goal setting (Singhani et al., 2022). This approach

also holds promise for reducing gaps between marginalized students, who often attend less well-resourced high schools and are thus less well-prepared for college than their counterparts from dominant groups (cf. Fink et al., 2020; Frey et al., 2018).

Barriers to Students' Adoption of Effective Learning Strategies

Spontaneous use of learning strategies requires more than knowledge, however. Students must often reframe how they understand the process of learning. By the time students reach college, they have spent the better part of two decades in school, typically without significant instruction in cognitive science research demonstrating that many of the most widely used study strategies are relatively ineffective. Not only do many students arrive at college gateway courses with a history of poor study habits, they often resist new study strategies because they cannot easily evaluate the quality of their own learning.

This occurs for two reasons. First, even relatively ineffective study strategies can produce short-term benefits, such as when students cram before an examination. Second, students often overestimate the benefits of weak learning strategies and underestimate the benefits of strong ones because the latter requires greater mental effort. Many students misperceive this sensation of mental effort as signaling failure to learn (e.g., Kirk-Johnson et al., 2019). In contrast, cognitive scientists who study students' choice of learning strategies identify this sensation of

mental effort as a natural by-product of fruitful learning. From this vantage point, effective learning strategies create "desirable difficulties" that enhance learning (Bjork & Bjork, 2011, p. 55). To adopt effective learning strategies, students need to believe the greater effort required by these strategies is worth their time (e.g., Yan et al., 2016). And they need support in developing concrete, practical plans to apply the strategies to their coursework.

In this article, we describe a learning-strategy intervention to overcome barriers that often deter students from using effective learning strategies. We provide preliminary results of a randomized study as early support for the intervention's positive academic outcomes. The intervention can be tailored to varied settings and purposes, including existing tutoring and coaching programs and individual courses.

The Coaching to Learn Project

Our project aimed at developing a relatively short, peer-to-peer learning strategy training program that could be embedded into an introductory university STEM course rather than a stand-alone science of learning course taught by an expert, as described in McDaniel and Einstein (2023). We were interested in promoting students' self-regulated learning through the use of specific cognitive strategies central to effective study. We focused on strategies that the cognitive science literature has revealed to be effective across multiple disciplines (Dunlosky et al., 2013; Pashler

et al., 2007). Our goal was to provide college students with a generalizable toolkit of cognitive strategies that they could apply to a variety of courses, and in so doing, improve their academic performance in demanding gateway STEM courses and throughout their college career. To achieve this goal, we incorporated key elements into the learning-strategy training that aligned with the Knowledge, Belief, Commitment, and Planning (KBCP) framework (McDaniel & Einstein, 2020; McDaniel et al., 2021).

We were also committed to a peer-to-peer based delivery model. A growing body of evidence supports the effectiveness of peer-based programs, particularly when training is ongoing and of high quality (Cooper, 2010; Dawson et al., 2014; Munley, et al., 2010; Topping, 1996). Students may find advice and instruction from peers to be more credible and relevant to their own college experiences (Cutright & Evans, 2016). And students can speak directly to those experiences. Another major reason is that peer-based delivery is scalable to large courses without the prohibitive expense of supporting a large staff of experts to provide the strategy training.

Knowledge, Belief, Commitment, and Planning (KBCP) Framework

A robust literature has underscored the difficulty of implementing learning-strategy training programs that promote students' sustained self-regulation and transfer of those strategies across a range of content. As Hattie et al. (1996) concluded from their meta-analysis of learning skill interventions, it is difficult to change study skills that students have acquired, and older students, including those at the college level, are more resistant to change. In considering received theories of self-regulated learning and the associated cognitive, metacognitive, and motivational research, McDaniel and Einstein (2020) suggested that four key elements needed to be incorporated into a training program to successfully support students' self-regulation of effective learning strategies.

(1) Students need **knowledge** about effective learning strategies. Many college students appear to be unaware of effective learning strategies (Bjork et al., 2013; Karpicke et al., 2009). And students face numerous challenges in developing effective study strategies on their own, including inaccurate metacognition and absence of objective access to effectiveness of learning strategies (McDaniel and Einstein, 2020) and biases toward less-effortful strategies (Kirk-Johnson et al., 2019).

(2) Students need to **believe** that those effective strategies work for them. In one set of experiments, Yan et al. (2016) were generally

unsuccessful in convincing students of the value of interleaving or mixing material across different concepts relative to blocking study on one concept before moving to the next concept. They concluded that it is difficult to overcome students' "willingness, even eagerness, to believe that 1 is unique as a learner—that what enhances others' learning differs from what enhances one's own learning" (Yan et al., 2016, p. 918). Only when each student participated in a demonstration in which they applied the interleaving strategy and the blocking strategy separately to two different sets of concepts and received an explanation of the superiority of interleaving relative to blocking, did students express a belief that the interleaving strategy was indeed more effective. In line with this finding and following from McDaniel et al. (2021), in the current training program we relied in part on demonstrations in which students participated to reinforce belief that the target strategies were effective for them.

(3) Students must **commit** to using the learning strategy. With insufficient commitment to the strategy, students may know about the strategy and believe that it works for them but be reluctant to exert the effort required to implement the strategy. For example, Wang et al. (2023) developed an intervention to teach students about the efficacy of retrieval practice and how to implement it flexibly through various formats. Yet, students' usage of the retrieval practice strategy

was negatively impacted by the cost of engaging in retrieval practice (too much time and effort involved).

(4) Students must adequately **plan** for how and when to use the strategy. Students may have knowledge about an effective strategy, believe that it works, and be reasonably motivated to use it; but without adequate planning the strategy may not be incorporated into their study routines (e.g., Hartwig & Dunlosky, 2012). For instance, in a survey an overwhelming majority of undergraduates (85%) attending a variety of institutions (universities, four-year colleges, and community colleges), endorsed a spaced study strategy ("studying the material in multiple sessions") relative to a massed study strategy ("studying the material in one longer session"; Susser & McCabe, 2013). However, the strategy that students reported actually using to study for a test did not overwhelmingly incorporate spacing; students did not report using spaced study more often than massed study. Students can talk themselves out of intentions to use effective study strategies because of time pressure (e.g., Maurer & Shipp, 2021) or competing priorities (Marsh et al., 1988). Accordingly, following findings that training for planning produces positive effects on self-regulated strategy use (Dignath et al., 2008; Donker et al., 2014), we included a planning component to the current training program. We now turn to a more detailed description of our intervention, followed by preliminary results supporting its promise.

Overview of the Knowledge-Plus Intervention

Knowledge Plus is a four-week, eight-hour intervention embedded in Calculus 1 at Syracuse University, a large, private research institution in Central New York. As explained further below, it is part of the larger Coaching to Learn Project. The intervention is administered by learning center professionals and student staff with collaboration from the Math faculty. The peer coaches are hired at least one semester prior to the start of a given coaching semester and receive at least 10 hours of training, including practice simulations, before they begin coaching and six or more additional hours of training during their first semester coaching. Training is certified through the College Reading and Learning Association's International Peer Educator Training Program and focuses on communication, ethics, and effective learning strategies rooted in cognitive science. Coaches are not required to have participated in coaching or to have taken Calculus 1, although many do one or both.

Students are scheduled to participate in two, hour-long coaching sessions per week for four weeks. The first session consists of a one-on-one meeting between the student and their assigned peer coach. During this session, the peer coach uses an interactive curriculum to introduce the student to that week's set of learning strategies and a related set of study skills or "tools" the student chose among for implementing the strategies. The

coach supports the student in making specific plans to try these tools and strategies in the upcoming week as they study for specific courses, including but not limited to Calculus 1.

A day or two after this one-on-one session, students attend an hour-long "supported study" session. Supported study is also led by a trained peer coach but involves groups of three to six Calculus 1 students. Supported study provides a scaffolded setting in which students discuss and compare their individual experiences experimenting with the week's broad learning strategies and more specific study tools. These sessions aim to bridge the gap between more tightly structured one-on-one coaching sessions and independent studying students do outside of coaching.

Conducting an evaluation of an intervention of this kind requires significant resources to allow for access to and monitoring of student data, Institutional Review Board approval for planned research, and close collaboration with the faculty in whose courses the intervention is embedded. However, the Knowledge-Plus intervention was deliberately designed so that interested learning centers and individual faculty can incorporate elements of the curriculum into their existing programming and/or courses, and to encourage those who are interested to collect data and analyze results. To facilitate this possibility, the following section provides a detailed description of the four-week Knowledge-Plus curriculum,

including illustrations and examples from each of the eight component hour-long sessions.

The Knowledge Plus Curriculum

The curriculum introduces students to one broad set of learning strategies each week and supports students in experimenting with varied options or "study tools" for implementing these strategies. (The content of each week is described more fully in subsequent sections of this article.) All these strategies require students to actively direct their learning using self-regulation and metacognition. This approach takes more effort than commonly used passive strategies, such as re-reading or reviewing math problems for which solutions are provided but yield better results (Bjork et al., 2013; Lawson et al., 2021). Peer coaches work with students at each weekly session to personalize the conversation and support students in planning how they will apply the new strategies in the upcoming week, not only in Calculus 1 but in other courses they are taking. This approach is designed to emphasize that the learning strategies are not domain specific while providing students with concrete illustrations of ways to apply the strategies to both calculus and non-calculus coursework.

By explicitly recognizing that more effective learning strategies feel harder but become easier over time and with practice, peer coaches encourage students to persevere in

experimenting with new strategies and seek to normalize feelings of initial discomfort or frustration. The goal is for students to adopt strategies they prefer and use them in ways they find sustainable. How well and with how much detail a student would be able to explain a particular strategy one or two semesters after coaching is of less concern than whether the student adopts elements of one or two of the strategies into their study routines and applies them across courses.

One-on-One Coaching Sessions

The one-on-one sessions are designed to share several common components. Each session introduces one focal set of effective learning strategies, while also foreshadowing strategies that will be covered in future weeks and reviewing those from previous weeks. This approach limits didactic content to manageable amounts and encourages students to draw connections across the four sets of learning strategies and consider using them in combination. Each session features engaged conversation between the peer coach and the student and includes one or two hands-on activities that promote this conversation. The coach walks the student through a set of PowerPoint slides. The slides are designed to support coaches in personalizing material to the interests of individual students while also fostering programmatic fidelity and a baseline for consistency across coaches and sessions. Each set of slides also features deliberate opportunities for students to share their ideas,

ask questions and voice concerns. Session-specific learning objectives are presented early in each session and reviewed before the session ends. Coaches are trained to present "no stakes quizzes" about previous weeks' materials as opportunities for effective learning and to draw students out in a friendly, supportive manner.

Supported Study Sessions

Like the one-on-one coaching sessions, the supported study sessions share key components across the four weeks. Each week, the peer coach opens supported study with introductions or re-introductions, making sure that students recall one another's names and establishing a friendly atmosphere that encourages all students to participate by drawing them into opening small talk. In the second part of supported study, the coach prompts students to engage in a retrieval exercise in which they recall the study plans they made during their earlier one-on-one coaching session that week. The students write down a brief account of their experiences. The coach then guides the students through a group conversation about these experiences, including successes and challenges. The coach works to draw students out and to address misunderstandings and concerns about the strategies and study tools.

The third segment focuses on a specific study skill that utilizes the week's set of learning strategies. The coach introduces this

"spotlight study tool." The coach then leads the students in using the tool together. At the end of each supported study, students have time to apply the tool individually or in pairs as they complete calculus homework or study for an upcoming calculus exam. The coach circulates and supports students in applying the learning strategies to calculus, not to assist students in understanding calculus concepts or arriving at the correct answer to specific calculus problems.

This final part of the session allows the coach to model the use of one study tool and related broader learning strategies and gives students the opportunity to practice on their own while the coach fields questions and offers encouragement. Overall, supported study sessions are designed to bridge the gap between highly structured one-on-one coaching sessions and studying students do on their own outside of coaching and to encourage students to develop the confidence and competence they need to use effective learning strategies independently.

Students are intentionally scheduled to meet with the same peer coach on the same day and time for all one-on-one sessions and with the same coach and fellow students on the same day and time for all the supported study sessions. This promotes consistency and routine, barring the need to reschedule.

Week 1: Retrieval and test-enhanced learning. During the first one-on-one coaching session, the peer coach establishes a

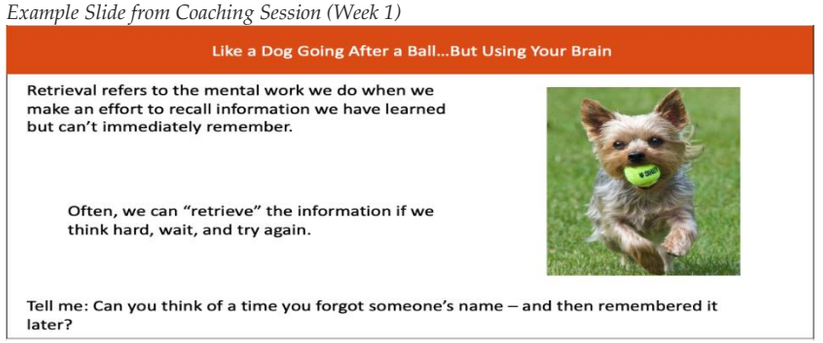
relationship with the student. They exchange basic information, such as their hometowns, how they came to the University, and how the students feel about taking Calculus 1. The coach explains that coaching can help students who feel confident about calculus study more efficiently, while students who find calculus challenging can benefit by studying more effectively. Then, following the PowerPoint presentation slide sets used for each one-on-one coaching session, the peer coach explains that the coaching program is based on a large body of cognitive science research that includes findings many college students find counterintuitive, including that rereading, highlighting, and reviewing problems with step-by-step solutions are relatively ineffective strategies (Bjork, et al., 2013; Karpicke, et al., 2009). Learners can succeed in mastering courses and subjects they fear or have done poorly in previously if they employ effective learning strategies that emphasize deeper understanding over superficial memorization.

The coach emphasizes that learning requires connecting new material to prior knowledge and then invites the student to engage in an activity based on McGuire's (2015) Count the Vowels exercise. This exercise helps students appreciate the value of context and pattern identification for interpretation and recall of otherwise isolated facts and provides an entry point for conversation about retrieval. The coach then introduces our

analogy of a "study toolbox" consisting of four sets of drawers. Each drawer contains one set of effective learning strategies but includes multiple specific study "tools" from which the student can choose to implement the strategies. The coach explains that the first set of strategies is called retrieval and invites the student to guess at what "retrieval" might mean in this context while displaying an image of a dog retrieving a ball (Figure 1). This approach deliberately foreshadows learning strategies that will be introduced in subsequent coaching sessions. At the end of the session, the coach introduces potential "tools" for implementing retrieval and explains that the students will be asked during their upcoming supported study to reflect on their experiences experimenting with three retrieval tools. The coach then walks the student through selecting which tools they will try and planning how to use them in specific courses as they study in the days before their supported study session.

Figure 1

Example Slide from Coaching Session (Week 1)



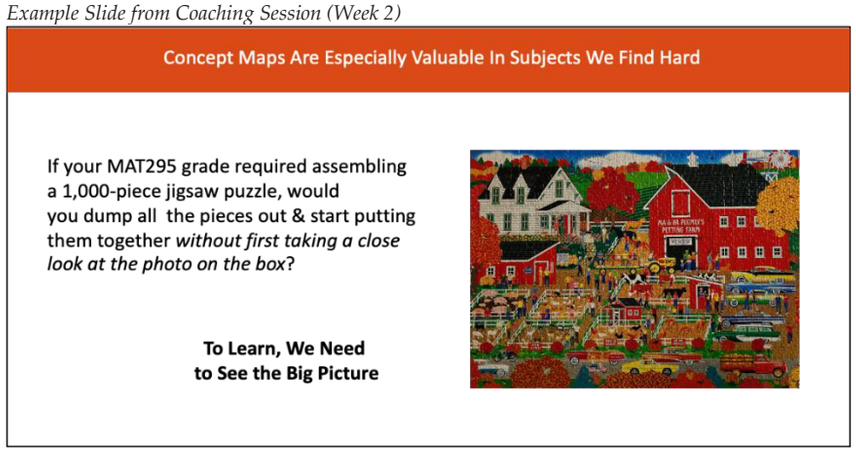
During the Week 1 Supported Study session, students use mind mapping to practice retrieval, emphasizing the value of creating a visual tool that includes text and drawing. In this instance, mind mapping is introduced as a straightforward tool for retrieval; the coach encourages students to brainstorm whatever relevant information they can recall about the topic selected for the "mind map" and jot that information down on paper in any order or format they like. The students work as a group to create a mind map for the University. Then, continuing to work as a group, they start another mind map, this time of their Calculus 1 course. The coach invites each student to contribute a topic or concept to the mind map, such as "limit" or "derivative," by retrieving relevant information from memory. Students then spend the remainder of the hour working individually or in pairs to continue building out their own Calculus 1 mind map.

Week 2: Organization. Week 2 introduces two forms of organization: organizing course material effectively to foster lasting understanding and organizing the time students spend studying to make that time as productive as possible. During this week's one-on-one session, the coach introduces the student to several techniques they can use to organize concepts, procedures and other course material they are learning. These include creating concept maps, making outlines and classifying course

material based on the student's self-rated level of understanding (previously known/learned; new knowledge as of today; in-progress knowledge/not fully understood). The coach emphasizes how these types of organizational study tools help students see "the big picture" and achieve a deeper, more cohesive understanding than is possible through more typical efforts to memorize discrete facts or techniques. One slide asks: "If your MAT 295 [Calculus 1] grade required assembling a 1,000-piece jigsaw puzzle, would you dump all the pieces out and start putting them together without first taking a close look at the photo on the box?" (Figure 2). Throughout, the PowerPoint slides present and repeat imagery combined with text that reinforces one another and supports students' dual coding of learning strategies and related concepts through complementary neural pathways for processing textual and visual information (Mayer & Moreno, 2003).

Figure 2

Example Slide from Coaching Session (Week 2)



The second one-on-one session also includes a calendaring exercise to promote time management and a growth mindset assessment to foster motivation and encourage persistence. The Week 2 supported study session includes discussion of students' experiences experimenting with organizational strategies and cements understanding of concept maps, which were introduced during the previous, one-on-one session as an organizational tool distinct from mind maps in their emphasis on illustrating relationships among terms, concepts, and procedures students are learning in a course. The coach leads the group in beginning to create a concept map for Calculus 1 on a white board, inviting each student to contribute at least one feature they recall from the course. The coach reminds students of the advantages of combining imagery and text to promote retrieval and organization. Students spend the remainder of the session completing their own Calculus 1 concept map individually or in pairs and using the concept map to study for the course.

Week 3: Spacing and Interleaving. The third one-on-one session introduces students to the advantages of spacing compared to massed practice (Figure 3) and interleaving related material within a course or between courses that share common concepts (Figure 4). The coach explains the value of guessing at answers to questions one has not yet been taught and explicitly introduces the concepts of "productive failure" and "desirable

difficulties" in learning, which have been foreshadowed in earlier one-on-one sessions (Clark & Bjork, 2014). The coach briefly describes research studies of the value of spacing and interleaving in mathematics and engages the student in reflecting on their assumptions and feelings about learning Calculus and other challenging academic subjects. The coach points out that we are often more accepting of the idea of learning from mistakes and experiencing learning as challenging outside of traditional academic contexts, such as team sports or studying a musical instrument. The third supported study session introduces the students to Venn diagramming as a tool they can use to identify related concepts that lend themselves to interleaving. The coach leads the group in creating a Venn diagram identifying similarities and differences across baseball, football, and basketball. The students then create a Venn diagram identifying related concepts within Calculus 1 or between Calculus 1 and other courses they are taking, such as Physics 1.

Figure 3

Example Slide from Coaching Session (Week 3)

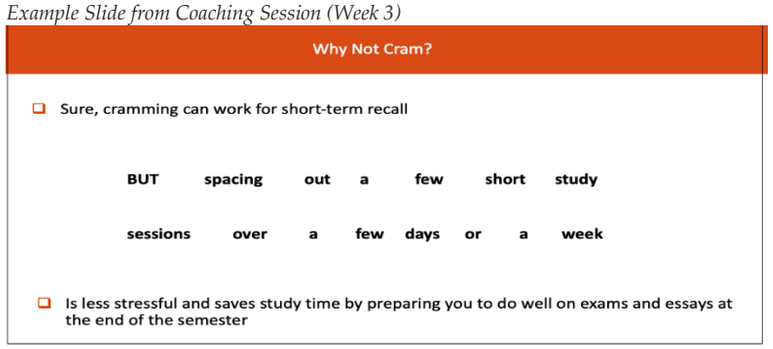
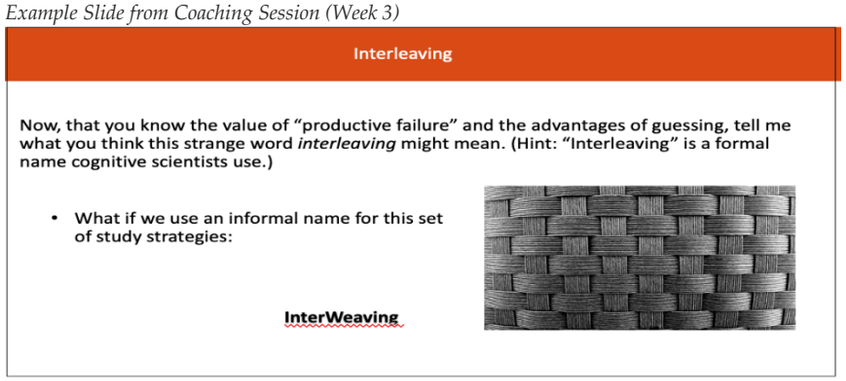


Figure 4

Example Slide from Coaching Session (Week 3)



Week 4: Elaboration and Explanatory Questioning. The final week of the curriculum focuses on elaboration and explanatory questioning as well as combining the four sets of effective learning strategies during independent study. The one-on-one session emphasizes taking stock of students' feelings about the strategies and the mental effort they require. The coach compares developing good study habits to judiciously adding salt to food; adding some effective strategies into existing study routines is the goal, not reinventing oneself as a student or dramatically increasing study time. The coach encourages the student to "be patient with yourself" and recognize that making even small changes to study routines is hard work (Figure 5). The final supported study session likewise emphasizes student choice and opportunities to experiment with combining the learning strategies.

Figure 5

Example Slide from Coaching Session (Week 4)

The Randomized Trial

A central aspect of our Coaching to Learn project is a comparison of outcomes from the Knowledge-Plus intervention with a loosely parallel, four-week "Knowledge-Only" intervention. The Knowledge-Only intervention consists of a set of four online modules and four related quizzes focused on the acquisition of knowledge about the learning strategies. This "active control" is designed to reflect a "standard" strategy-training approach that focuses solely on information about effective learning strategies. All students enrolled in the target course (Calculus 1, as described below) were randomly assigned to one of the two interventions, thereby ensuring a high standard of rigor comparing outcomes for these two groups. This design is advantageous in that it tests the value of the KBCP theoretical model, which posits that knowledge about the strategies per se is insufficient to motivate most students to adopt more effective learning strategies. This evaluation answers

the question: Are there differences in student performance for those who were randomly assigned to Knowledge-Only coaching compared to those randomized to Knowledge-Plus? This approach allows us to create roughly parallel experiences and incentives for students participating in the two interventions. While a control group that did not receive the intervention would allow us to determine the impact of the Coaching-to-Learn program generally, ethical concerns related to the potential disadvantage in Calculus I for untreated students made this choice untenable.

General Method

The research team collaborated with the Math Department at Syracuse University to embed the two interventions in Calculus 1, a large course taken by a diverse group of approximately 700 students annually and widely perceived by students as challenging. The complete evaluation of this program involves interventions over four semesters beginning in Fall 2022 and concluding in Spring 2024. In each 14-week semester, Calculus 1 students were randomly assigned to the Knowledge-Only or Knowledge-Plus groups. Completion of the program counts for four percent of students' final calculus grade regardless of treatment group. To earn this four percent, students need to complete their randomly assigned treatment (eight, hour-long coaching sessions for the Knowledge-Plus group and four online

modules followed by four quizzes for the Knowledge-Only group) and pre- and post-intervention learning strategy surveys. Students provided informed consent for use of their data in the research project. All research protocols were approved by the University's Office of Research Integrity and Protections.

Although the randomized trial is scheduled to end following the Spring 2024 semester, data collection and analysis will continue until the Spring of 2025. Students who participate in coaching will be followed for at least two additional semesters afterward to allow collection of individual course grade and semester grade point average data. We will also collect multiple, detailed sources of student self-report data about their study strategies before and after the intervention and their attitudes toward the intervention to which they were randomly assigned. Below, we describe planned analysis of all four cohorts of coaching students along with a preliminary analysis of the final exam scores in Calculus I for the Fall 2022 cohort.

The quantitative and qualitative measures that we are collecting and analyzing as part of the Coaching to Learn project derive from four sources: (1) student demographic, socio-economic, and academic information available through Syracuse University's administrative data systems, including gender, race-ethnicity, citizenship, first generation status, high school grade point average, Calculus 1 exam and course grades, other course grades, and

progress toward graduation; (2) a version of the Motivated Strategies for Learning Questionnaire (MSLQ) (Jackson, 2018; Pintrich et al., 1993) modified to incorporate new items directly relevant to coaching on retrieval, organization, spacing and interleaving, and elaboration; (3) responses to brief sets of survey questions embedded in the Knowledge-Only modules and the Knowledge- Plus coaching sessions, which probe students' reactions to the intervention and to the learning strategies; (4) a new Study Strategy Survey developed by the intervention research team to probe lasting understanding of the learning strategies among coaching students who go on to take Calculus 2 and the degree to which students spontaneously transfer these strategies to their study routines for this course. Calculus 1 students completed the modified MSLQ before they begin coaching and after they complete coaching.

Preliminary Results from Fall 2022

Completion Rates. In the Fall of 2022, most Calculus 1 students completed their assigned treatment. Interestingly, completion rates were higher among the Knowledge-Plus treatment although this treatment required in person participation and offered less scheduling flexibility than the online modules. Specifically, 78 percent of the 197 students randomized to the Knowledge-Plus treatment completed the pre- and post-coaching MSLQ and attended their eight coaching

sessions, compared to 70 percent of the 201 students randomized to the Knowledge-Only treatment who completed the pre- and post-coaching MSLQ and the four online modules and quizzes.

Preliminary Academic Outcomes. The Fall 2022 Calculus 1 students randomly assigned to the Knowledge-Plus group outperformed their Knowledge-Only counterparts on the Calculus 1 final exam score. Intent to Treat (ITT) results, which included all students in both treatment groups regardless of whether they completed their assigned intervention, found that the average final Calculus exam scores of Knowledge-Plus students were 3.4 points higher than those of Knowledge-Only students (t-test; $p<0.08$; 100-point exam scale). These ITT regression analyses controlled for student year, citizenship, first-generation status, high school grade point average, and engineering versus other majors, as well as stratification by under-represented minority status and Calculus 1 section. (Further details are available from the authors upon request.)

Conclusions

The Coaching to Learn project has established several notable advances. First, we have demonstrated the viability of a theoretically guided learning strategy intervention that incorporates cognitive and metacognitive elements consistent with the KBCP framework (McDaniel & Einstein, 2020). These include transmitting **knowledge** about generally effective learning strategies and

illustrating specific study procedures to implement those general strategies (through one-on-one coaching and small-group supported study sessions); fostering students' **belief** that the strategies work for them (through exercises and peer-led discussion of students' successes with the strategies); forging students' **commitment** to apply the strategies in their course (through peer-supported study sessions and discussion of how to adapt and use the strategies in their courses); and encouraging students to **plan** to integrate the strategies into their study activities (through follow-up activities that were revisited in subsequent sessions). The intervention is tractable on a number of dimensions. It is relatively short (2 hours/week for four weeks); it is implemented within a particular academic course (rather than a semester-long 3-credit course dedicated to learning strategy training; McDaniel et al., 2021) and it likely can be implemented as a 4-week workshop at college learning centers; it is scaled for use in a very large enrollment introductory college course; and it does not require hiring of professional university staff, relying instead on peer-to-peer coaching.

Second, we have shown that the four-week Knowledge-Plus intervention is acceptable to students. In the Fall 2022 trial, 78 percent of the students randomized to this Knowledge-Plus intervention completed the curriculum. Third, in an initial evaluation of the Knowledge-Plus intervention relative to a more

basic Knowledge-Only comparison, students in the Knowledge-Plus intervention had better final exam scores in the Calculus 1 course in which the intervention was embedded. Thus, Knowledge-Plus peer coaching curriculum may improve students' academic performance, at least in the semester in which the students engage the curriculum. Future data collection and analysis will allow us to more fully evaluate the impact of the intervention, including the transferability of skills outside of Calculus and the sustainability of benefits over time.

We hasten to acknowledge that there are limitations of the evaluation study. The Knowledge-Only treatment involved only half the instructional time devoted to the Knowledge-Plus treatment. Thus, it remains possible that if the time feature was comparable, Knowledge-Only would fare as well as the Knowledge-Plus treatment. Further, the Knowledge-Plus treatment involved in-person coaching, whereas the Knowledge-Only control was self-administered (online). Accordingly it remains possible that the delivery method per se could play a role in better outcomes for Knowledge-Plus. Additionally, for ethical reasons we did not assign students to an inactive control group. It may be that the Knowledge-Plus treatment produces even more dramatic academic benefits relative to students who receive no instruction in effective learning strategies. At present, it is likely that a high proportion of today's college students receive either no learning strategy instruction or

ineffective instruction. Coaching to Learn is one approach that might help remedy this unfortunate situation. Our hope, especially if the complete results continue to show success, is that this initial account of the intervention will inspire learning center professionals and faculty to consider adopting and adapting elements of our Knowledge-Plus curriculum to their programming and courses.

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