Evolving study strategies and support structures of introductory physics students

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Students often struggle in the transition from high school to college. One component of this struggle is adjusting study habits to navigate new academic expectations. Another is establishing new relationships in college that can support their emotional well-being and academic success. We administered surveys consisting primarily of open-ended questions to students taking an introductory physics course in order to gain insight into students' study habits and support structures and how they change from high school to college. We find that many students learn that they need to dedicate more time outside of class to studying in order to succeed in college. Many students trying to improve their performance report practicing more, but our results suggest that more practice alone is not sufficient; rather, students were able to increase their performance and satisfaction in the course by engaging more deeply with the material. Regarding support structures, we find that in high school, students find their teachers highly supportive and accessible, but they are less likely to approach their college professors for help. Meanwhile, many students find peers to be an important source of support in college as the amount of support they receive from their families diminishes with distance from home. Gaining a better understanding of students' study habits, support structures, and how they conceptualize them can help us design course structures and messaging that can more effectively help students develop strong learning strategies and social networks.

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I. INTRODUCTION

Students often struggle in the transition from high school to college [1–5]. One component of this struggle is adjusting study habits to navigate new academic expectations. Another is establishing new relationships in college that can support students' emotional well-being and academic success.

While several studies report on the study habits of college students [6–10], they are often students recruited from psychology courses. However, it is clear that physics classes require students to adopt different strategies than what they use in other courses. Hora and Oleson [11] conducted focus group interviews with students in science, technology, engineering, and mathematics majors about their study habits and found that physics courses stood out for problem solving being an essential part of studying. Elby [12] found that students conceptualize "trying to do well in the course" as a different activity from "trying to understand physics well," where they believe that doing well requires a focus on formulas and practice problems, and understanding requires more focus on concepts and real-world examples. Furthermore, it is difficult to influence students' study behaviors. For example, Zhang *et al.* [13] conducted interventions aimed at providing students with more accurate information about their preparedness for an upcoming exam, improving metacognition, and reducing cramming behavior, but student behavior and performance were unchanged.

Much of the literature on study strategies was published prior to the widespread use of online homework and practice tests [8–10,12]. Now that students can receive immediate feedback on their work and are not as often expected to submit detailed written solutions, their strategies and engagement with course materials may have changed.

Previous work has shown the importance of social support for college students. Thompson [14] developed a measure of peer support, and with Mazur [15], implemented it to find that students most valued support from their peers where they could vent about their difficulties, followed in level of importance by informational support, esteem support, and motivational support. Mishra [16] conducted a review of existing literature to find that students' networks of support that include family, faculty, and identity groups contribute to their academic success. We extend this work by examining how students' support networks shift from high school to college.

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To better understand how students' strategies may have changed with the availability of new technological resources, we administered a series of surveys to students taking an introductory physics course. We investigated how students adapt their study strategies from high school to college and how their support structures shift during the transition.

II. RESEARCH CONTEXT AND METHODS

Students were recruited from an introductory, calculus-based mechanics course at a large, public research university in Spring 2022. The course consists of 2 h of interactive lecture per week led by a professor with 300 students per section, 2 h of small-group problem-solving discussion led by a graduate teaching assistant with up to 24 students per section, and 2 h of lab led by two graduate teaching assistants and an undergraduate learning assistant with up to 74 students per section. In this course, students take three exams throughout the semester followed by a final exam. Students have access to exams given in prior semesters through their online homework system. These practice exams include immediate feedback and video explanations of the problem solutions. Students are also given a concepts-focused review assignment to complete prior to each exam. Students complete weekly homework online and a weekly quiz in their discussion sections. Course grades are assigned according to the number of points earned across the various components of the course, with grade intervals predefined and communicated to students at the beginning of the course. Students are not in competition with each other for their grades.

After their first exam, the researchers gave the entire class a short survey in their online homework system asking them to rate the similarity of their study strategies for physics exams in high school and college; students were asked to rate the similarity of their strategies for exams 1 and 3 following the third exam as well. The wording of these questions is provided in Appendix A.

Everyone in the class received a recruitment email inviting them to participate in the study; 100 students out of 288 volunteers were selected to participate. These students were selected at random within bins by exam 1 score such that students with lower scores were oversampled since historically, we have seen students with low scores in our courses have been more likely to drop out of our research studies. Ten students were selected per exam score bin, each of which has a width of five percentage points with the exception of the lowest bin, below 55%. Furthermore, students were selected such that each Likert-scale response category to the whole-class survey question regarding the similarity of their high school and exam 1 study strategies was represented within each exam 1 score bin. A total of 83 students completed both the first and second surveys, and 74 students completed the third survey. Figure 1 shows the exam 1 score distribution of the 74 students who completed all three surveys along with the score distribution of the whole class. The greatest attrition took place for students with exam 1 scores between 55% and 65%; in the end, our sample overrepresents the 65%–70% score range and underrepresents the 85%–90% exam 1 score range.

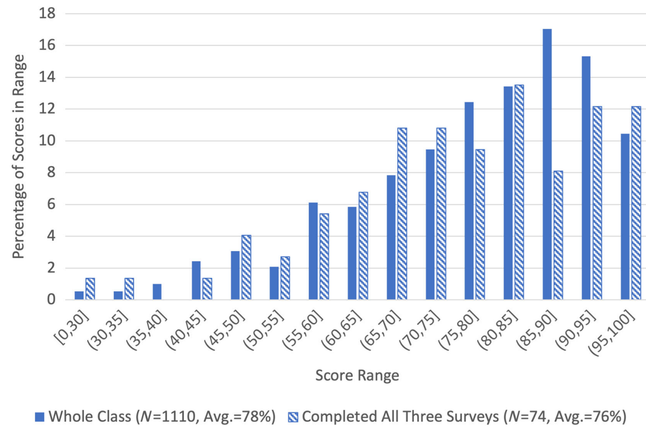

FIG. 1. Exam 1 score distributions of the subset of the class that completed the study and the whole class.

While the demographics of the study participants were for the most part similar to those of the whole class, women were overrepresented in the study, comprising 45%, as compared to the class population (28%). The demographic data of the students in the study and in the class as a whole are shown in Table I.

The 100 selected students were invited to complete an online written response survey after each of the three exams given in the course, not including the final exam. Students were financially compensated by increasing amounts for the completion of each survey but were not invited to complete later surveys if earlier surveys were not completed. The full text of the surveys is reported in Appendix B.

In the first survey, students were asked about their prior physics experience. About 78% of the students had taken an advanced placement (AP), international baccalaureate (IB), or comparable physics course. Just 4% of the students

TABLE I. Demographics of the class and study participants.

Demographic	Whole class (%)	Completed study (%)
American Indian/Alaskan native	<1	1
Asian	45	50
Black	3	5
Native Hawaiian/Pacific Islander	<1	0
White	52	47
Multiple races	5	7
Hispanic	13	18
International	15	11
Women	28	45
Nonbinary	<1	0

had not taken physics in high school. These students are especially well prepared: just 42% of the American high school class of 2019 had taken any physics course in high school [17].

A coding scheme was developed for each unique written-response survey question based on emerging themes. Two researchers (D. S. and D. G.) independently coded the responses for each question and then compared the results, discussing areas of disagreement. If substantial disagreement occurred, the coding scheme was collaboratively modified and the researchers again independently recoded the responses. This process was iterated until a reliable coding scheme was established. The average value of Cohen's Kappa for the final independent coding was 0.79, indicating substantial agreement. Any disagreements were discussed, and the two coders eventually reached 100% agreement on the coding for each question.

III. RESULTS AND DISCUSSION

A. Grades and satisfaction

In each survey, participants were asked to rate how satisfied they were with their exam score on a five-point Likert scale from very satisfied to very dissatisfied. Figure 2 shows the satisfaction levels for each exam. Participants were generally dissatisfied with exams 1 and 2 and became more satisfied with their scores on exam 3, despite the average exam score of the whole class decreasing.

In general, satisfaction and grades were correlated, with participants scoring higher on their exams being satisfied and participants scoring lower being dissatisfied. Figure 3 shows the exam scores by satisfaction level. The width of each box plot corresponds to the number of participants represented. The dark vertical bars represent the median of the distribution, the left end of each box represents the 25th percentile, and the right end of each box represents the 75th percentile. The whiskers represent the end points of each distribution, with outlier data points included for scores

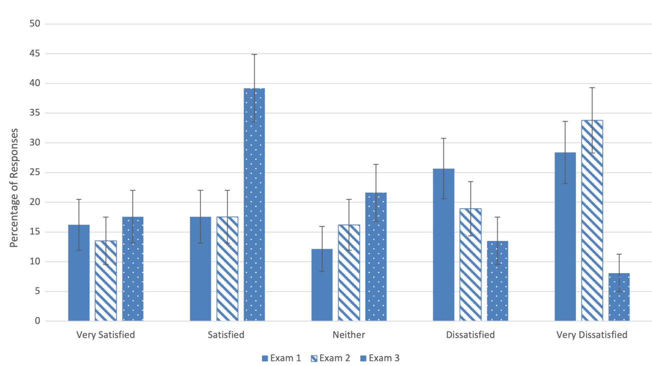

FIG. 2. Student responses to the question, "How satisfied are you with your exam score?" Complete cases, $N = 74$, are represented. In this figure and all others with error bars, the size of the error bars is one standard error.

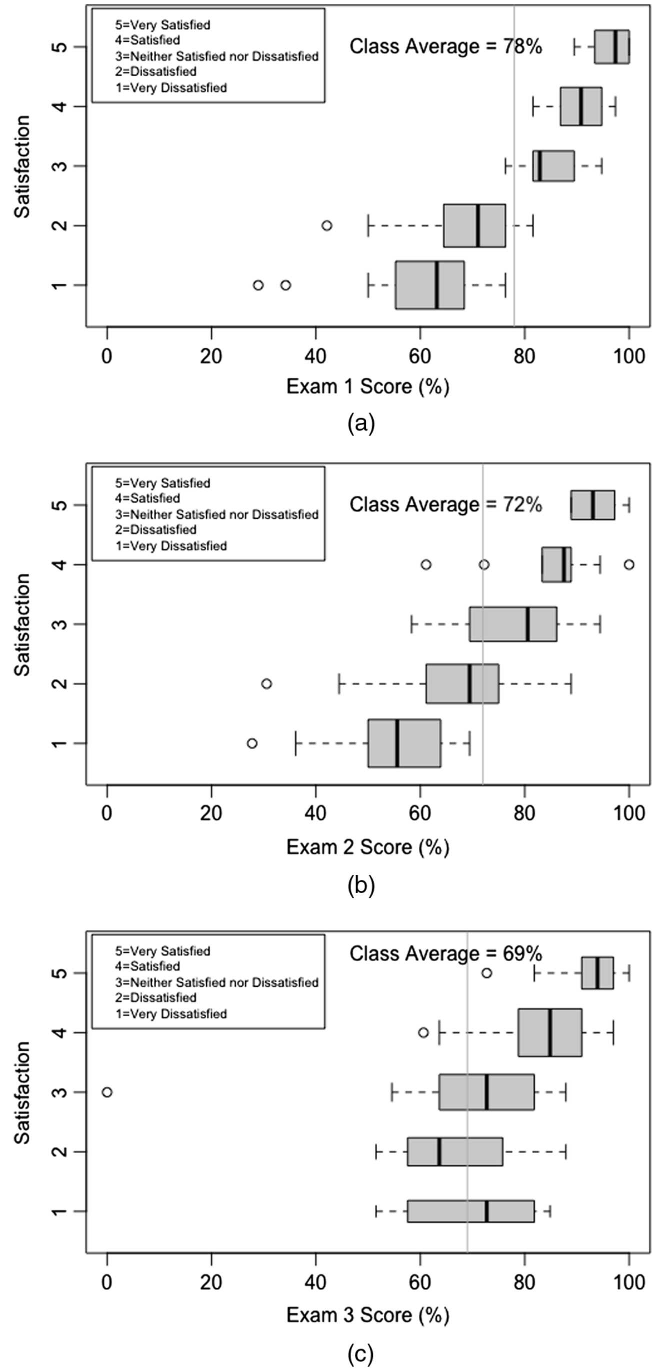

FIG. 3. (a) Exam 1 satisfaction vs score. (b) Exam 2 satisfaction vs score. (c) Exam 3 satisfaction vs score.

outside the third quartile plus 1.5 times the interquartile range or below the first quartile minus 1.5 times the interquartile range.

On exam 1, participants were dissatisfied with grades below the class average of 78%. For exam 2, there is a larger spread of scores for students who were neither satisfied nor dissatisfied. For exam 3, there was a larger spread of scores for participants who were neither satisfied nor dissatisfied, dissatisfied, and very dissatisfied, and a great deal of overlap between the lowest three satisfaction levels. There were only six participants who were very dissatisfied. Three of these individuals scored well above the class average but still reported being very dissatisfied, perhaps because they scored higher on previous exams. Since students have their own goals for the course, we include both their exam scores and satisfaction in our analysis.

B. Study strategies

Participants were asked to list the study strategies they used to prepare for their physics exams in high school and college. In both cases, most participants engaged in some form of practice, typically from class-provided practice exams. Participants also got help from their high school teachers and college instructors outside of class (e.g., office hours), received tutoring, and formed study groups with their classmates. Many participants reviewed their class notes for their high school exams and for the first college exam but did not continue using this strategy for later exams. Similarly, some participants reported that going to class and doing work as assigned was enough to prepare them for their high school exams and their first college exam but not for subsequent exams. This is likely due to the overlap in material from high school and the beginning of the college course. A few participants also reported memorizing formulas and watching videos.

In high school, participants reported they did the bulk of their studying while still in the classroom. Class time was often used to finish homework and complete practice problems. Most high school teachers devoted at least one class period to exam review and gave participants study guides to complete. If participants still had questions, they would meet with their teachers before or after school for help. This was much more common in high school than in their university course. Participants also received help from their friends and continued to do so in college. No participants reported getting help from a tutor while in high school, but some went to a free walk-in tutoring center available to engineering students at their university.

1. Practice exams

In each survey, participants were asked what they believed were the most effective aspects of their studying in both high school and college and why. Most participants reported that completing practice problems was the most effective study strategy in both high school (61%) and college (78%) because the problems were similar to the actual exam and they could identify concepts they were confused about. Some students reported that these practice problems were provided by their instructors and usually in the form of practice exams, but high school teachers also provided review packets and study guides. In their college course, students were provided with four practice exams for each exam, and 88%, 89%, and 95% of students surveyed reported using them to study for exams 1, 2, and 3, respectively.

In the second survey, participants were also asked what they hoped to gain from using practice exams (if they used them at all). The responses are consistent with the results we found for the “most effective study strategy” question. Most participants used the practice exams to determine which topics would be covered, the kinds of problems that could be asked, and the difficulty level of the exam. By doing the practice exams, students narrowed down the concepts that could appear on the exam and gained insight on examlike questions. Participants used these exams to increase their confidence and learn how to effectively solve these questions. Participants also used practice problems and exams to help identify areas of confusion and ensure they understood the concepts. If participants understood the questions related to a particular topic, they believed they mastered the concept. If they did not understand, then they would revisit the material, usually in the form of a notes review. Frequencies of different types of student responses regarding their use of practice exams are represented in Fig. 14 in Appendix C. Practice done from homework or discussion packets was found to be far less helpful because the problems were often considered too difficult and different from actual exam questions.

Although most students made extensive use of practice exams, there remained a large variation in their exam performance. In the next section, we examine the changes students made in their exam preparation strategies alongside their exam scores and satisfaction with exam performance.

2. Biggest change

From the whole-class surveys issued after the first and third exams, we gain insight into how students changed their study strategies between high school and college physics (Fig. 4). Regarding the similarity of study strategies

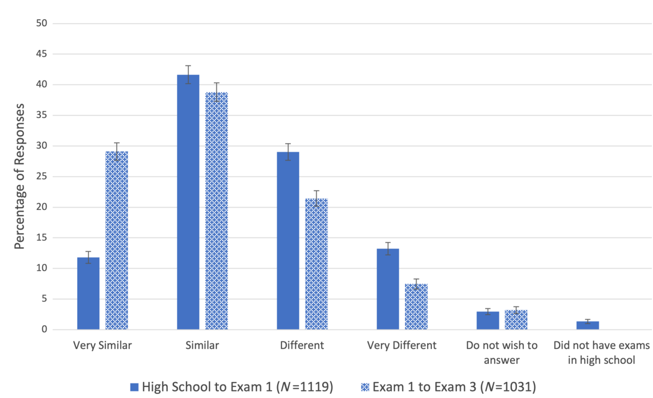

FIG. 4. Whole-class survey responses to questions asking students to compare the study strategies used in high school to the first exam and the first exam to the third exam. See Appendix A for wording.

between high school and college exam 1, 54% of students reported using similar strategies while 42% reported using different strategies. Between college exam 1 and exam 3, 68% of students reported using strategies that were similar while 28% reported using strategies that differed. While these responses tell us that most students used similar strategies, based on the responses the participants gave in the written surveys, students likely found practice exams to be the most helpful study resource and continued using them throughout the semester.

We gain further understanding into these changes when examining the responses of the study participants. After each exam, participants were asked to reflect on the biggest change they implemented while preparing for their exam compared to how they prepared for their previous exam (Fig. 5). The responses included themes we refer to collectively as "higher engagement" that did not emerge in other parts of the surveys. The code for higher engagement can be broken down into four categories. The first is an emphasis on mastering concepts. This includes participants going beyond memorizing equations or procedures and trying to understand the topics at the conceptual level so they are able to approach any type of problem. The second is engaging in the course, which means participants worked to be more involved during lectures and discussions and keep up with the course material. The third category is about participants' increased motivation, effort, and seriousness in college compared to high school. The final category is for participants who incorporated a new practice strategy in their study routine. For example, many students indicated they not only spent more time working through each practice exam problem but also spent more time reviewing the solutions to make sure the answers made sense. They also mentioned making a complete and thorough attempt to solve practice exam problems prior to looking at the solution videos. A few participants also reported taking the practice exam in examlike conditions. The frequencies of these by exam are represented in Fig. 15 in Appendix C.

Compared to high school physics, participants reported spending more time studying for their first college physics exam (about 3 h more) and felt more motivated to do well, in part due to the pressures of being in college:

> The biggest change I have implemented in preparing for my [course] exam compared to AP Physics in high school would be that I actually study on my own time now. These exams are not open note tests, the classes are taught in person, I am a freshman, I am paying for my tuition, and I am majoring in physics... compared to high school, I felt a lot more pressure to do well and thoroughly understand this course's material.

For the second exam, participants spent an additional hour studying compared to exam 1. They also reported starting their preparations sooner, on average about a quarter of a day, and practicing more. For the third exam, participants reported spending more time studying; however, the number of hours they reported was about the same as the second exam. It is possible that the time they spent studying was more meaningful and thus felt longer. It is also possible that they were not accurately tracking the time they spent studying. They also reviewed additional materials, like their homework or prelecture videos.

While the data suggest that preparing earlier and spending more time result in a higher change in exam scores (Fig. 6), we believe that in addition to benefiting from spaced practice [18], the increase in exam scores may also derive from students' availability to do so (e.g., fewer time commitments). It is important to note that participants who spent less time studying reported being overwhelmed with other responsibilities, either academic or personal, and these changes were not necessarily intentional:

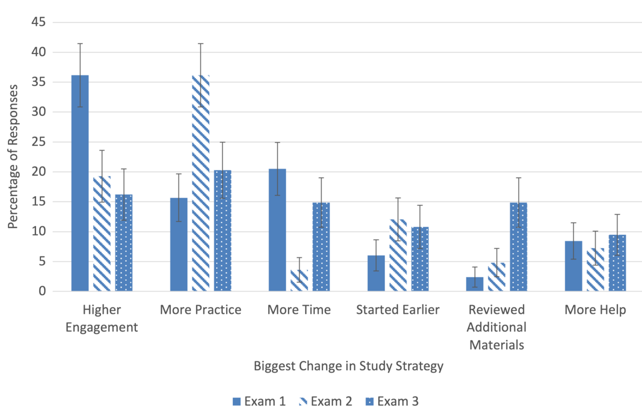

FIG. 5. Student responses to the question "What do you think is the biggest change you have implemented in preparing for exam N compared to exam $N-1$?". Many students mentioned multiple changes, and each of these is included.

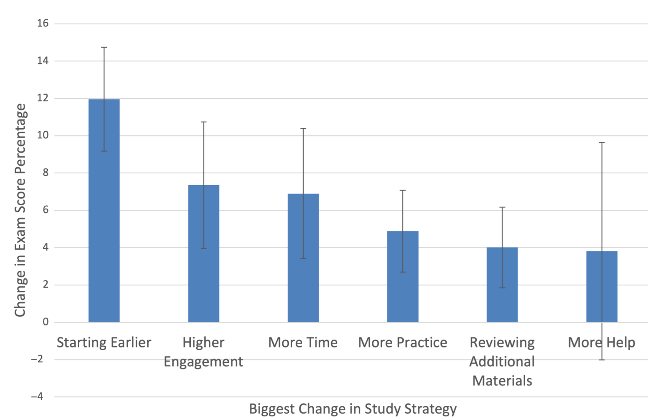

FIG. 6. Average change in exam score by biggest change in preparation strategy. Changes in exam scores are adjusted by the average change in exam score between consecutive exams in order to aggregate the data from multiple exams.

> The biggest change was not studying as early as I should've, [I] was tired of everything with projects, long homework assignments, and assessments left and right.

Comparing participants who became satisfied with their exam scores to participants who became dissatisfied or whose satisfaction was unchanged, a higher proportion reported they spent more time studying and were more highly engaged in the course (Fig. 7). Participants who remained satisfied were more likely to start studying earlier and participants who remained dissatisfied were more likely to report practicing more and getting more help. This is not to suggest that getting help is inherently linked to dissatisfaction; rather, a student who is struggling with the material could be motivated to seek out help last minute and not have the time to consolidate the material learned prior to the exam. The same can be said about more practice. Furthermore, a student practicing less effective strategies may not benefit as much from that additional practice.

A study by Zhang *et al.* [13] found that the format of the practice exams could lead students to have "an illusion of understanding" (p. 686). The practice exams provided by the course offered instant feedback with video solutions and provided a grade that could be updated with each additional attempt with no point penalties. As such, the grade was not a true reflection of their exam preparedness. Students may tend to overestimate their ability and be more disappointed in their actual exam scores. This phenomenon may explain why, although students who practiced more experienced an increase in their exam score on average, they were more likely to end up dissatisfied than satisfied. In contrast, engaging more deeply with course material could foster a genuine sense of accomplishment in the students when their progress is internally evaluated rather than externally evaluated by an inflated practice exam score.

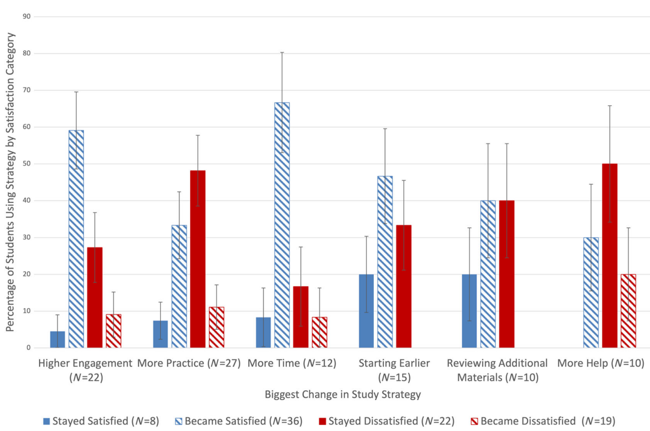

FIG. 7. Change in exam score satisfaction by biggest change in preparation strategy. The graph shows the percentage of students who reported each strategy as their biggest change categorized by change in satisfaction. Students represented in the stayed satisfied or dissatisfied categories reported the same satisfaction for all three exams. Students in the became satisfied or dissatisfied categories could have become satisfied or dissatisfied at either exam 2 or exam 3 and could be counted in both categories if their satisfaction changed at both time points. Some students reported more than one strategy as their biggest change and are represented in the columns for each strategy they reported.

C. Sources of support

1. Changes from high school to college

Following exam 2, we asked student participants who supported their academic success and emotional well-being in high school and college, and how these sources of support have changed (question wording available in Appendix B 2, questions 10–15). Four key sources of support emerged in the students' responses: family, teachers, peers, and themselves. We saw major shifts in the sources of support mentioned for high school compared to college. As shown in Fig. 8, the number of students reporting self-reliance and reliance on peers for academic support increased from high school to college, while the number of students reporting academic support from their families and teachers decreased. One student explained the shift they experienced in academic support as follows:

> Academic support came to me in high school as something that was required. My teachers would make the effort to reach out to me if my grades dropped, my counselors would schedule meetings with me to make sure I was on track to achieve the things I needed to achieve to succeed in school and ultimately college, and my parents would regularly check my academic progress (either ask me stuff or look at my report cards and talk to my teachers). However, I have found in college that I have to be more active in getting the academic

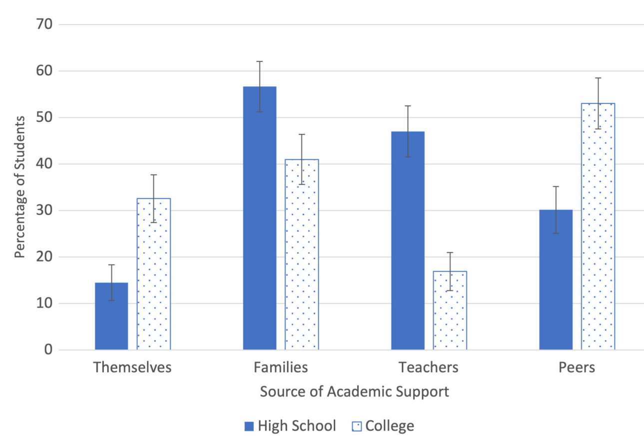

FIG. 8. Summary of student responses to the questions, "Who supported your academic success in high school?" and "Who supports your academic success in college?" ($N = 83$).

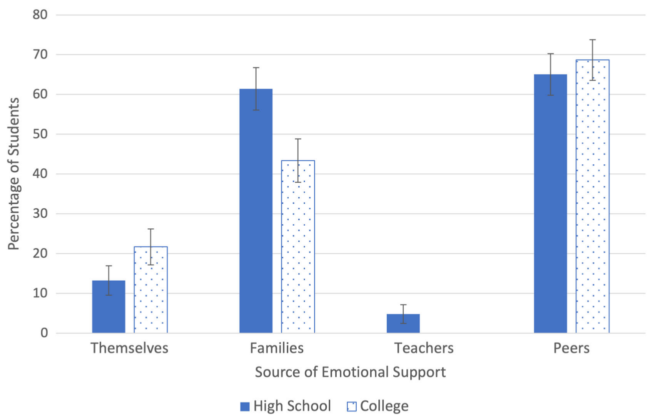

FIG. 9. Summary of student responses to the questions, "Who supported your emotional well-being in high school?" and "Who supports your emotional well-being in college?" ($N = 83$).

> support I need; I need to reach out to professors and TAs, I need to ask the right questions during lectures and discussions, and I need to set up meetings with my academic advisors if I'm struggling. There's definitely more responsibility for me and in some ways, this is helpful because I don't need to spend time in meetings that I don't need to have, but on another hand, I might dig myself into a hole without realising it in the future.

Figure 9 shows that friends were an important source of emotional support in both settings, while, as with academic support, family support decreased. Teachers were rarely a source of emotional support in high school and were not mentioned at all by respondents as a source of emotional support in college. Describing the shift from high school to college, one student wrote,

> I have become more dependent on my friends and myself in order to maintain my emotional support. I no longer have my parents and siblings in the room next to me. I must make an effort to connect with friends and practice independent support if I want to improve my emotional support.

Students were 4 times as likely to report a higher intensity of emotional support from their friends in college than to report a lower intensity compared to high school. Overall, 60% of students indicated changes in their sources of emotional support as they transitioned to college, and 73% reported changes in their sources of academic support.

2. Family support

In addition to identifying who they looked to for support, students also described how these individuals supported them. We found that most of the support students wrote about receiving from their families, even the academic support, came in the form of encouragement. Students also mentioned family supporting them through accountability or checking in with the student, offering a home environment conducive to academic success or academic or financial resources, academic assistance, and academic advice. Students framed encouragement as "pushing me to try my best" (high school) and "still encouraging me when I feel disappointed by my failures and celebrating my successes" (college). While students mentioned their parents checking in with them in both settings, the intensity decreased from high school to college. In high school, this looked like "asking me every day about new grades/homework assignments and...tell[ing] me to study for a test all the time"; in college, it was simply "ask[ing] how things are going." On the topic of financial support, students wrote about having "the opportunity to prioritize studying over finding a job or paying for expenses" in high school and "pay[ing] for my tuition and get[ting] me any resources I need to study" in college. Few students wrote about receiving academic assistance or academic advice from their parents in either high school or college. From the responses, it seems that not only is encouragement the most common type of support students receive from their parents but also that it is highly valued by students both in high school and college.

3. Instructor support

Nearly half of the students identified their high school teachers as a source of academic support; fewer than one-fifth mentioned their college instructors. Students talked about these instructors differently as well: overall, their relationships with their college instructors seemed to be less personal. Students generally described both high school and college teachers as helpful, but high school teachers in particular were described also as accessible; encouraging, motivational, and inspirational; a trusted source of advice; aware of individual students' learning; and checking in with students on their well-being and academic performance. Examples of how students wrote about each of these characteristics of their instructors are shown in Table II. Meanwhile, in describing interactions with college instructors, one representative student wrote,

> Some professors are really passionate in teaching and I feel that I'm learning things in lecture with them. TAs for the most part are really helpful in filling in gaps in my knowledge during labs/discussions or office hours. Friends from lab/discussion/project groups or social circles give me everything from laughter, encouragement, and stern advice when I need it.

This student writes very positively about their instructors but describes less personal relationships and less

TABLE II. Characteristics of teacher support in high school. Percentages are out of the number of students (39) indicating academic support from their high school teachers.

Characteristic	Percentage	Example
Accessibility	46	*My teachers because we were able to at any time to go to our teachers and ask them questions. I also had two study halls in high school and one of them was an all school study hall, so it was the perfect time to ask any teacher any question you may have had.*
Encouragement, motivation, and inspiration	26	*My chem teacher because he motivated my fuel to study better. He was always guiding on how to do better.*
Offering advice	21	*My math teacher supported me the most by becoming my mentor and regularly helping me with problems inside and outside the classroom*
Aware of individuals' learning	15	*I believe my high school teachers were much more close to me and so they could have a chance to see how I am learning and what they can do for me to learn better.*
Checking in with students	10	*My teachers because they were very involved with how I was doing and reached out whenever they noticed my grades were lower than usual.*

accessibility than how we see students describe their high school teachers.

Student responses to the Likert-scale question, "How would you rate the approachability of your (a) high school physics teacher; (b) [course] discussion TA; and (c) [course] lecturer?", shown in Fig. 10, are consistent with their written descriptions of their interactions with instructors. Students rated the approachability of their discussion TAs similarly to that of their high school teachers, predominantly as "Very Approachable." Meanwhile, the most common response regarding their lecturers was one unit lower, "Approachable." This may be related to the smaller class size of the discussion sections, capped at 24 students, similar in size to a high school classroom and much smaller than the lecture sections of 300 students. For example, one student referenced class size as follows: "I believe TAs and myself are responsible for my success in college so far. I think I have learned more in smaller TA discussions rather than large lectures. Most TAs I have had so far have been very helpful." Students may also have found their TAs more approachable than their professors because they are typically closer in age to the undergraduate students, are students themselves, and have less power than faculty. Accordingly, one participant wrote, "I feel more comfortable with [TAs] as they are students just like me." Although students rated their TAs as similarly approachable to their high school teachers, we still do not see the depth of relationship reported that we do for high school teachers in the written responses; perhaps, the smaller number of contact hours (about five per week for high school teachers vs two for discussion TAs) and the broader availability of high school teachers outside of class (often available before and after school and during their prep periods vs the TAs' one office hour per week) could explain the difference.

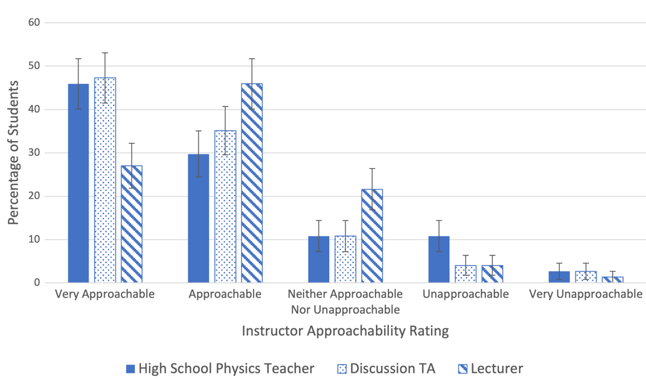

FIG. 10. Student responses to the Likert-style question, "How would you rate the approachability of your (a) high school physics teacher; (b) [course] discussion TA; and (c) [course] lecturer?" ($N = 74$).

Most students surveyed never or rarely visited the course office hours, as shown in Fig. 11. Of the students surveyed who never attended office hours, slightly more than half explained that they did not feel the need to attend because they felt comfortable with the material, did not have questions they wanted to ask, or were getting help from other sources, most commonly peers or the Internet. Slightly fewer than half of students who never attended office hours wrote that office hours did not fit into their schedules.

Of the students indicating that they had attended office hours, half referenced difficulty with the material as the reason for attending, while about a third cited their busy schedules as the reason for not attending more often. Considering all responses (whether they had attended office hours or not), students were about equally likely to conceptualize office hours as a place where they could discuss concepts and address general understanding and a place where students should have a specific question to attend.

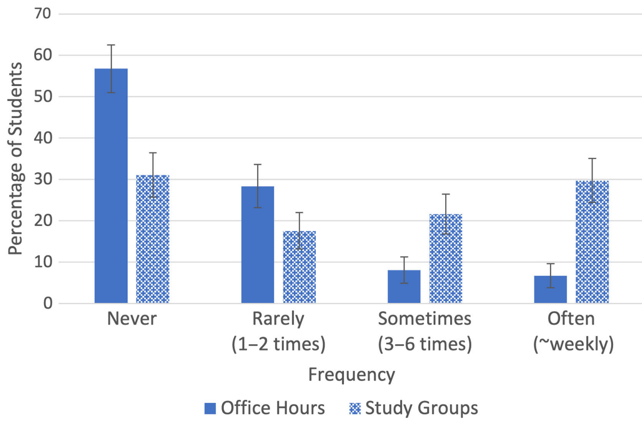

FIG. 11. Student responses to the questions, "How many times have you been to [course] office hours?" and "How many times have you studied with your physics classmates outside of class?" ($N = 74$).

4. Peer academic support

In the transition from high school to college, the nature of peer academic support changes. Not only did more students cite their peers as a source of academic support in college than in high school, but also a greater fraction of these referenced direct support with course content. Furthermore, a far greater fraction of students indicated academic support as a combination of encouragement and help with academic content or studying together (Fig. 12). It seems that peer academic support is not only more prevalent in college than in high school but also plays a more comprehensive role in students' lives.

Student responses about studying with peers offer more insight into how peer academic support operates in their physics class. As shown in Fig. 11, nearly a third of students studied with their physics classmates outside of class on a weekly or more frequent basis, while another third never studied with classmates. It is far more common for students to study with peers than to attend office hours.

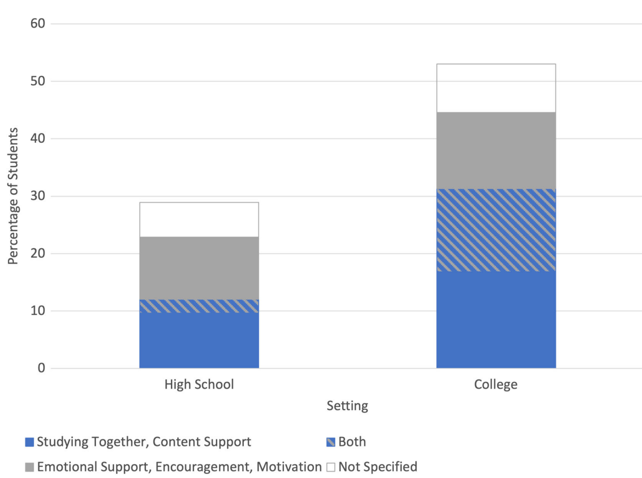

FIG. 12. Nature of peer academic support described by students ($N = 83$).

Of students who reported that they never studied with classmates, 57% felt that they worked better alone—for example, "I prefer to study alone, as I get distracted when others are with me." However, 35% of students studying alone wrote that they have trouble finding people to study with; as one person described, "I am an introvert and I do not have any friends and it is hard for me to approach someone to study so I end up studying alone." These responses suggest that students may benefit from additional course structures that could help them connect with peers to study with outside of class.

A large portion of students (44%) who had studied with others 3 to 6 times over the course of the semester did so specifically to prepare for exams; the same percentage of these students wrote about the value of learning from their peers. One student who studied with others to prepare for exams wrote,

> I often find that studying with my peers can be helpful because I can reinforce my knowledge of a topic if it is a bit lacking by listening to someone else who might understand it better. Basically, I can get another perspective or explanation for how to do a problem. (Of course, I also study alone to make sure I can individually apply my knowledge for the exam.)

About 63% of students who often worked with others wrote about learning from other students: "I prefer studying in a group because they help me understand topics." Meanwhile, 32% of regular study group participants wrote about helping others, with most of these describing the help as reciprocal: "Whenever I'm stuck I want to get help to understand it. Also I will sometimes study with others if I know they need to study or need help." Students value the insights of their peers, and many recognize that their own contributions are valuable as well, and are happy to support their friends.

5. Peer emotional support

Although students reported peer emotional support at similar rates for high school and college, their responses directly comparing the emotional support they received in high school and in college indicated a greater intensity of emotional support from friends in college concurrent with diminished support from family; for example, students wrote,

> My family is a lot less of a support because I hardly see them anymore, but I see my friends a lot more than I used to and they support me a lot more.

and "Now that I have met new friends and we live in close proximity, I have many more peers who support me emotionally."

The nature of peer emotional support in high school and college was described similarly by the students. In both cases, support generally took the form of either conversation or relaxing together. Conversation helped students process difficulties and strategize how to solve personal problems, and friends cheered them up and encouraged them. For example, one student wrote about their high school friends,

> My friends also supported my emotional well-being and we would just talk about the things that bother us and just generally talk things out and it really helped having someone to talk to.

Similarly, about their college experience, another wrote,

> My friends support my emotional well-being. Active listening is a strong pillar in my relationship with my friends. We are able to talk, rant, and support one another in all circumstances.

Sometimes direct conversation about difficulties was not what students felt they needed most but rather spending time relaxing with friends and taking a break from their day-to-day responsibilities. About their high school experience, one student stated,

> My friends did. Mainly by hanging out and just relaxing together. We didn't ever have heart to heart conversations about our mental health, but it was understood that hanging out and going on hiking/kayaking trips together (our shared hobbies) helped our mental states.

About college, a participant wrote,

> One of the things supporting me emotionally is making sure I relax each week and get to hang out with my friends, so the stress from school does not overwhelm me.

These students have found that balance is important for them to be well, and friends are an important part of maintaining a balance between schoolwork and self-care.

6. Self-reliance

About twice as many students wrote about self-reliance in college as compared to high school. While the number of students citing themselves along with others as sources of academic support increased slightly, the number of students citing only themselves as a source of academic support more than tripled (Fig. 13). Some students wrote about motivation and working hard:

> The only who that supports my academic success is me, but the thing that motivates me is my goal to become an astronaut. I support myself by always evaluating my goals and prioritizing the subjects where I have lacking skills.

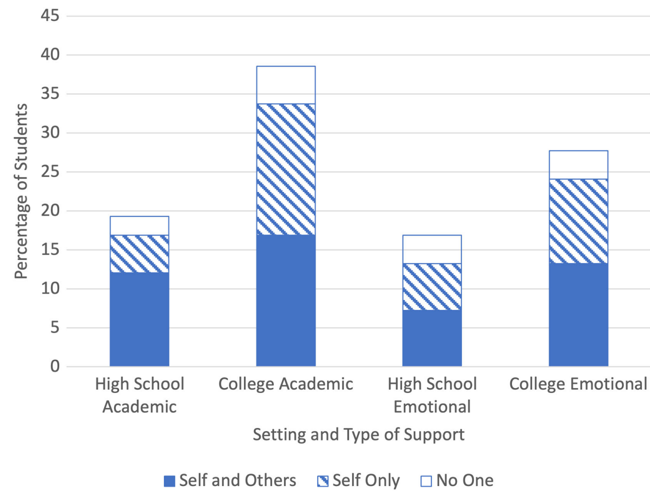

FIG. 13. Student indications of self-reliance in detailing their sources of academic and emotional support in the high school and college settings ($N = 83$).

Others seemed to miss having more academic support, like this student who felt academically supported by classmates in high school: "No one really, I haven't made too many friends in college that I consistently hang out with yet, so it's really just me pushing myself to succeed." Meanwhile, some students referenced self-reliance alongside a variety of other sources of support:

> My parents, by listening to me; my friends, by studying with me and answering my questions; my boyfriend, by encouraging me; my advisor, by also encouraging me; and myself, by being resilient and forthright.

Regarding sources of emotional support, some students wrote about finding their own way as adults ("Me; Trying to be independent and become a strong adult") or by taking care of themselves ("Just me. I've got some hobbies I like doing and they keep me happy, so far.") Others wrote about taking responsibility for their own emotional well-being in part by spending time with friends:

> In college, my emotional well-being has become much more dependent on my own state of mind. One of the things supporting me emotionally is making sure I relax each week and get to hang out with my friends, so the stress from school does not overwhelm me.

Still others highlighted a lack of support: "Myself. No one checks in on me emotionally. I am all on my own again. I will carve out time daily for my mental health." While the increase in self-reliance is a positive change as students adjust to adult life in college, students reporting that they feel they have no sources of support is concerning. It may be worth identifying more ways to help students connect with their peers in the course to foster a greater sense of community for these students.

IV. CONCLUSIONS

A. Summary of findings

The transition from high school to university can be difficult for students to navigate. We have found that not only must students adjust what they need to do to succeed in their courses but also where they seek support.

Students made considerable use of practice exams in their college courses and believed them to be the best study tool available. Our data did show an increase in the average exam score for students who reported practicing more. Despite the average improvement seen with more practice, even among these students, there was a large range of test scores, and many students remained dissatisfied with their scores even when they did improve.

Study strategies like starting earlier and spending more time also resulted in an average increase in exam scores, and those students were more likely to be satisfied with their exam scores by their third exam. However, one cannot simply conclude that starting earlier will lead to greater exam satisfaction. The ability to study earlier is likely correlated with many other factors such as workload and fatigue. Hence instructing (or requiring) students to practice more or begin studying earlier may not be enough to help them do well on their exams. Additional guidance on how to study more effectively could have a bigger positive impact on both exam performance and satisfaction. It is the intersection of the quantity of time spent and the quality of that time that is important to emphasize. These ideas were encapsulated in responses that we coded as higher engagement and showed substantial improvement in student satisfaction.

In the responses to survey questions about academic and emotional support, students illustrated the nurturing and mentorship they received from their high school teachers and how their primary source of support shifted to their peers when they came to college. Their high school teachers were aware of and responsive to student learning as well as accessible when students sought help and encouraged student success. While students generally found college instructors to be helpful, they did not offer nearly the level or scope of support that students received from their high school teachers. Hence, in college, most students adapted to their new environment by forming bonds with their peers at their mostly residential university. They wrote not only about the benefits of studying with others but also about how spending time with friends creates balance in their lives and helps them manage stress.

On the other hand, the number of students highlighting self-reliance increased substantially, approximately doubling between their reports of high school and college. While growing in independence and the ability to rely on themselves is a desirable development, we would hope that students would not feel completely alone, without resources or sources of support. Unfortunately, in this study, a concerning minority of students were unable to identify anyone they felt supported them in college or identified only themselves as a source of support. The latter category more than tripled in size with respect to academics between high school and college. Furthermore, a third of students who studied alone indicated a desire to connect with others but reported difficulty in doing so. In future work, we hope to further investigate if this lack of support persists and what resources are necessary to help these students succeed.

B. Limitations

This study was conducted in an introductory physics course for engineering and physical science majors at a large, public, residential research university, and the results may be specific to that context. With large class sizes and few contact hours with any given instructor, it makes sense that students find that they do not connect as strongly with their college instructors as they did with the high school teachers they saw every day in a smaller classroom setting. Similarly, freshmen at this university are required to live on campus; students attending a primarily commuter institution might find it more difficult to connect with peers than the students in our study. In the same vein, most of the freshmen at this university start their undergraduate degrees as full-time students immediately after high school, so the students in this study are young adults with the bandwidth to focus on their college educations and the impetus to develop new social networks in college.

Furthermore, the study focuses on how students navigate high-stakes testing specifically: students were asked about how they prepared for three 1.5-h, multiple-choice exams each worth 10% of their grade. Students not only need to understand physics concepts and be able to solve physics problems but also need to be able to demonstrate that knowledge in this format and time frame on the day of their exam. Therefore, it is natural that students highly value practice tests to acclimate themselves to how the questions are asked. Elby [12] found a disparity between how students reported studying for their exams and how they would advise another student unconcerned with grades how to learn physics deeply. We were encouraged to find that some students focused on understanding concepts and being able to explain physics ideas, and that these students were more successful on the exams than those who took a rote approach.

C. Recommendations

We believe that more can be done within the course structure to help students both in and out of the classroom without adding additional workload since many are already overwhelmed with other responsibilities. Based on student responses, we have several recommendations. At the onset of the course, instructors should explicitly set expectations and provide students guidance on effective study strategies. This is not meant to increase workload but rather prevent students from spending time on less effective study strategies, like rereading texts and reviewing lectures or notes. For example, participants noted that it was beneficial to take practice exams in examlike conditions, e.g., not reviewing notes, not looking at solutions, setting a time limit, and review their work for understanding afterward. Instructors could prompt students to explain their work on problems they had done with an emphasis on how physics principles inform the problem-solving approach [19]. In addition to supporting their learning and engagement [20], encouraging small-group work could help students form in-class networks that will ideally evolve into out-of-class networks, both of which could positively address the support concerns participants discussed in the surveys. This could appear as having students work together in lectures on clicker questions or as small-group problem-solving in discussion sections. Future research will investigate how the course structure can help facilitate effective student interactions with each other as well as the course content, as both appear to be important for their success.

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APPENDIX A: SURVEYS GIVEN TO WHOLE CLASS

Surveys were given after exams 1 and 3.

1. Survey 1

(1) Think back to the last physics course you took in high school, or if you did not take physics in high school, the course you consider most similar to [college physics course]. How similar were the strategies you used to prepare for exams in the high school course to the strategies you used to prepare for the first hour exam in [college physics course]?
- Very similar
- Similar
- Different
- Very different
- I did not have exams in my high school course.
- I do not wish to answer this question.

(2) Please explain.

2. Survey 2

(1) How similar were the strategies you used to prepare for exam 3 to the strategies you used to prepare for exam 1?
- Very similar
- Similar
- Different
- Very different
- I do not wish to answer this question.

(2) Please explain.

APPENDIX B: SURVEYS GIVEN TO STUDY PARTICIPANTS

Surveys were given after each exam.

1. Survey 1

(1) What is the most advanced physics class you took in high school? If you did not take physics in high school, what class do you consider most closely related? Questions 2–9 will ask about your experiences in this class.
(2) Please describe in detail all of the activities you did to prepare for exams in the class described in question 1. When possible, please include the approximate amount of time you spent on each activity for a single exam and when these activities took place relative to the exam (e.g., the day before, one week before).
(3) In total, how much time did you spend outside of class preparing for an exam in the course described in question 1?
(4) In the course described in question 1, how much class time was allocated specifically to preparing for exams?
(5) Please describe in-class activities devoted to exam review in the class described in question 1.
(6) Please describe the resources provided to you by your high school teacher to prepare for exams in the class described in question 1. (e.g., practice exams, study guides, etc.)
(7) What do you believe were the most effective aspects of your studying to prepare for an exam in the class described in question 1? Why?
(8) How far in advance of an exam in your high school class did you initiate your preparation?
(9) What factors influenced when you started to study for your exams in the class described in question 1?

(10) Please describe in detail all of the activities you did to prepare for exam 1 in [college physics course]. When possible, please include when and for how long you engaged in each activity.
(11) What do you believe were the most effective aspects of your studying for exam 1 in [college physics course]? Why?
(12) How far in advance of exam 1 did you initiate your preparation?
(13) How much time did you spend outside of class preparing for exam 1 in [college physics course]?
(14) What factors influenced when you started to study for exam 1 in [college physics course]?
(15) What do you think is the biggest change you have implemented in preparing for your [college physics course] exam compared to how you prepared in high school, and what prompted that change?
(16) How satisfied are you with your exam 1 score?
  - Very satisfied
  - Satisfied
  - Neither satisfied nor dissatisfied
  - Dissatisfied
  - Very dissatisfied
(17) What, if any, changes do you plan to make in preparing for hour exam 2?

2. Survey 2

(1) Please describe in detail all of the activities you did to prepare for exam 2 in [college physics course]. When possible, please include when and for how long you engaged in each activity.
(2) What do you believe were the most effective aspects of your studying for exam 2 in [college physics course]? Why?
(3) If you used practice exams to study, what did you hope to gain from doing so?
(4) How much time did you spend outside of class preparing for exam 2 in [college physics course]?
(5) How far in advance of exam 2 did you initiate your preparation?
(6) What factors influenced when you started to study?
(7) What do you think is the biggest change you have implemented in preparing for exam 2 compared to exam 1, and what prompted that change?
(8) How satisfied are you with your exam 2 score?
  - Very satisfied
  - Satisfied
  - Neither satisfied nor dissatisfied
  - Dissatisfied
  - Very dissatisfied
(9) What, if any, changes do you plan to make in preparing for hour exam 3?
(10) Who supported your academic success in high school, and how?
(11) Who supported your emotional well-being in high school, and how?
(12) Who supports your academic success in college, and how?
(13) Who supports your emotional well-being in college, and how?
(14) How have your sources of academic support changed as you've transitioned from high school to college?
(15) How have your sources of emotional support changed as you've transitioned from high school to college?

3. Survey 3

(1) Please describe in detail all of the activities you did to prepare for exam 3 in [college physics course]. When possible, please include when and for how long you engaged in each activity.
(2) What do you believe were the most effective aspects of your studying for exam 3 in [college physics course]? Why?
(3) How much time did you spend outside of class preparing for exam 3 in [college physics course]?
(4) How far in advance of exam 3 did you initiate your preparation?
(5) What factors influenced when you started to study?
(6) How would you rate the approachability of your high school physics teacher?
  - Very approachable
  - Approachable
  - Neither approachable nor unapproachable
  - Unapproachable
  - Very unapproachable
(7) How would you rate the approachability of your [college physics course] Lecturer?
  - Very approachable
  - Approachable
  - Neither approachable nor unapproachable
  - Unapproachable
  - Very unapproachable
(8) How would you rate the approachability of your [college physics course] discussion TA?
  - Very approachable
  - Approachable
  - Neither approachable nor unapproachable
  - Unapproachable
  - Very unapproachable
(9) How would you rate the approachability of your [college physics course] laboratory TA?
  - Very approachable
  - Approachable
  - Neither approachable nor unapproachable
  - Unapproachable
  - Very unapproachable

(10) How would you rate the approachability of your [college physics course] laboratory learning assistant?
- Very approachable
- Approachable
- Neither approachable nor unapproachable
- Unapproachable
- Very unapproachable

(11) How many times have you been to [college physics course] office hours?

(12) What influences your decision to attend or not attend office hours?

(13) How many times have you studied with [college physics course] classmates outside of class?

(14) What influences your decision to study with others or alone?

(15) What do you think is the biggest change you have implemented in preparing for exam 3 compared to exam 2, and what prompted that change?

(16) How satisfied are you with your exam 3 score?
- Very satisfied
- Satisfied
- Neither satisfied nor dissatisfied
- Dissatisfied
- Very dissatisfied

(17) What, if any, changes do you plan to make in preparing for the final exam?

APPENDIX C: SUPPLEMENTARY FIGURES

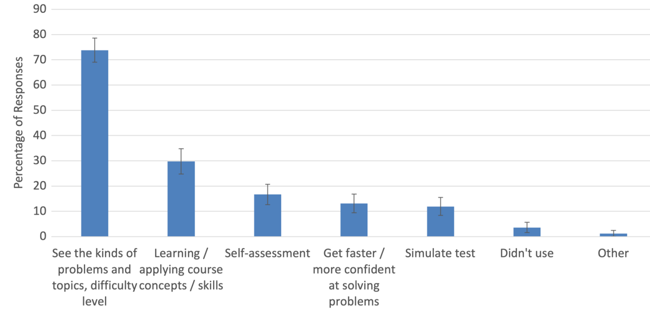

FIG. 14. Student responses to the question, "If you used practice exams to study, what did you hope to gain from doing so?".

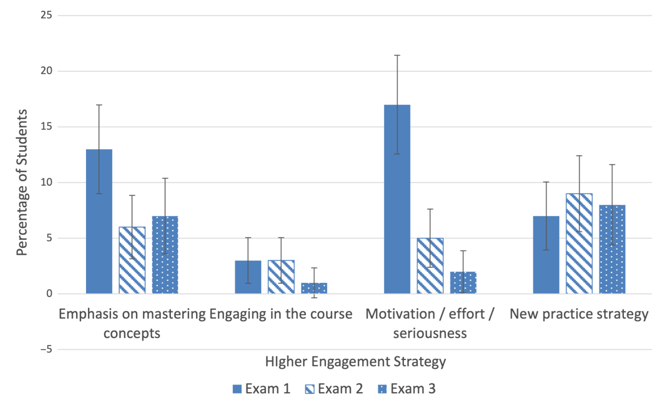

FIG. 15. Breakdown of higher engagement study strategies and their frequency in preparing for each exam.

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