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Students' use and perception of textbooks and online resources in introductory physics

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In this mixed-methods study of large enrollment introductory physics service courses, I investigated students' perception and use of online education resources as supplements to course-provided materials and activities. Specifically, I focused on the increasing use of popular free online media resources such as YouTube and Khan Academy, and fee-based textbook solution repository services such as Chegg. In the quantitative portion of this study, I surveyed students from three courses on their textbook and online resource usage and found that most students relied primarily on online resources as they navigated the courses, and comparatively few used the textbook regularly. In the qualitative portion, I investigated the patterns and culture of textbook and online resource usage via semistructured interviews and found that students reported using online resources as supplements to, or in place of, the course-provided materials when engaging with online homework or studying for an exam. Students reported using online resources productively to guide learning efforts, but also acknowledged unproductive uses such as copying solutions to mitigate loss of assignment points. I provide suggestions for changes in course materials, practices, and expectations to better engage students in the course and in their learning.

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I. INTRODUCTION

Textbook costs have risen at a greater rate than tuition and inflation and present a significant barrier to higher education affordability [1]. Students in their first year spent on average 20% more than upper division students on textbooks, which is particularly troublesome for first-generation students and low-income students who often lack support systems in their first semester [2]. Within this high-cost climate for traditional education resources, the 21st century university education setting must adapt to include open educational resources (OERs), which are free online resources such as (but not limited to) online textbooks, lectures, videos, simulations, and animations [3].

OERs have several advantages to traditional course materials: the materials are free to use with unrestricted access and easily accessible on most internet-capable devices, and empower students to independently control their own pace of learning [4,5]. Additionally, OER textbooks and materials lower student cost of learning and are at least equivalent and in some cases more effective than traditional textbooks for student learning outcomes [6,7]. Furthermore, OERs in conjunction with in-class activities encourage multiple representations of the content, providing greater opportunities for diverse student populations to learn [4,5]. Additionally, OERs encourage deep and meaningful learning of the content and the development of students' independent learning skills [8,9].

Adoption of OER textbooks and comparisons to print textbooks have previously been studied across disciplines [10–14] and within the context of introductory physics courses [15]. One may find a recent literature review of students' engagement with e-texts versus paper texts particular helpful for more information on this topic [16].

Studies have also been done that investigated the use of popular online media outlets such as YouTube [17] and Khan Academy [18] to supplement course activities and resources. The use of Khan Academy as a video learning component of flipped classroom models has been investigated in math education [19–21]. Other studies encouraged instructors to use YouTube as a medium to distribute their video creations to students [22–24], or for course activities in which students create videos [25,26]. As an alternative approach to creating content, related works focused on finding, compiling, and advertising existing online videos to share with students, essentially filtering content appropriate for their specific course context [25,27–33]. Furthermore, YouTube's broad impact as an education media platform sparked studies summarizing helpful tips for usage grounded in learning theories [34], as well as literature reviews on using YouTube in teaching activities across disciplines [35,36]. One study cautioned about a pitfall known as the illusion of understanding,

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commonly observed when watching others perform an activity without engaging in that activity, and analyzed the extent to which Khan Academy supports the illusion of understanding versus authentic understanding [37]. Based on this wealth of research, it is clear that such popular online media outlets have had a significant impact on education research over the past decade.

It is generally assumed that students engage with such online resources as needed for extra help during individual out-of-class activities, such as online homework. Online homework has long been promoted as comparable to pencil-and-paper homework for students' learning (as measured by standardized test scores), but with added benefits such as shortened feedback times and freeing up instructor time via automatic grading [38–42]. Online homework design choices have been studied, such as investigating the number of allowed attempts [43–45], and gender differences in how students approach multiple attempt methods [46]. Additionally, more detailed design choices such as whether to include embedded text versus linked text were compared, with students preferring the immediate availability of embedded text [47]. Studies involving online homework systems will continue to be important as online homework platforms evolve to incorporate new features such as process-specific feedback and force diagram assessment [48].

Instructors cannot prevent students from using online resources outside of class time. Rather than viewing students' use of online resources as something to be mitigated, a more productive path is to explore the reasons why and ways by which students use online resources in their course approach. Prior studies have explored students' resource usage when engaging in a homework assignment or long-term project in physics [46], computer science [49], chemistry [42,50], and economics [44,45]. However, I am not aware of any study that investigated students' perception and spontaneous use of culturally popular media and information hubs (YouTube, Khan Academy, Google, etc.) when engaging in homework in introductory physics. Additionally, students' perception and use of fee-based textbook solution repository websites such as Chegg [51] and Slader [52] generates concerns about authenticity of student work. The pervasiveness of such solution sites should encourage instructors to consider whether their online homework systems and activities reward copying rather than support individual exploration and learning.

Given the plethora of online education resources freely available, when engaging in course activities students encounter a choice to use course resources, online resources, or both. This study sought to better understand students' use of course resources and online resources as they engage with course activities. For example, students may use such resources to support their learning, or to circumvent learning by quickly finding an answer to the task at hand. Of particular importance in this investigation is to inform how our faculty might change course resources and expectations to better support students' productive engagement in their learning, and reduce the tendency to copy solutions. As such, rather than approaching this investigation by considering how to stop students from copying resources, I considered the ways our course resources and activities might have been deficient and drove students to seek external resources. Towards that end, this study addressed the following research questions:

1. What online resources are students using to supplement course-provided materials?
2. How frequently are students using these online resources?
3. For what purposes and in what ways are students using these online resources?

II. DESIGN PERSPECTIVE

This study was designed with a pragmatic worldview characterized by a focus on solving practical problems using empirical approaches, coming to better understand the world through experiences and actions, and considering the consequences of actions [53]. Pragmatic research emphasizes identifying a real-world problem, and using all available approaches to understand and solve that problem [54]. The problem I identified, which sparked this study, was the observation that students rely on resources outside of the course to support their learning and completion of course tasks. My perspective was that instructors' actions of choosing certain course structures, course resources, and grading expectations have consequences for how students approach the course. Through this lens, the problem identified here relates to a deficiency in course structure and resources in that students are finding outside resources more helpful than the very activities and resources for which they pay tuition. In this sense, the onus is on course designers and leaders to explore what resources students most frequently use, as well as why and how they use such resources, to inform how course methods and materials might be improved.

Generally speaking, students with more free time to explore outside of scheduled course times have greater opportunity to bridge gaps in their learning compared to students with low time resources. Findings from this study will inform course changes to provide students with better learning experiences for the money, time, and effort spent on course activities compared to the current structure. Specifically, one desired outcome of this work is reducing students' need for outside resources to bridge gaps in their understanding by having a greater depth and breadth of course resources that scaffold students' learning in a weekly cycle. An additional desired outcome is that such course changes result in greater benefits for students with minimal out-of-class time by having more learning-intensive in-class experiences during scheduled class activities.

III. METHODOLOGY

Following the pragmatic worldview described above, I employed a sequential mixed methods approach [54] starting with an online survey of a broad population of students in our introductory physics sequence for engineers, and following up with individual semistructured interviews of a subset of students who took the survey. All research activities described below were approved by Rutgers' Institutional Review Board.

A. Online survey

This study was conducted at Rutgers, The State University of New Jersey, which is a large research-intensive university supporting over 70 000 students from all 50 states and 125 countries, comprising one of the most ethnically diverse student populations in the country [55]. Approximately 81% of students are in state, and 19% out of state. Undergraduate students enrolled in an introductory calculus-based physics course sequence primarily for engineering majors responded to an online survey during the last 3 to 4 weeks of the Fall 2018 semester end date. A total of $N_S = 669$ students across three courses within the same two-year course sequence agreed to include their survey data in this study. This two-year course sequence is shown as Fig. 1, with first-semester students choosing between Extended Analytical Physics 1 (EAP1, $N_{\mathrm{EAP1}} = 91$) or Analytical Physics 1 (AP1, $N_{\mathrm{AP1}} = 427$), and both of those pools of students combining the second year into Analytical Physics 2 (AP2, $N_{\mathrm{AP2}} = 151$).

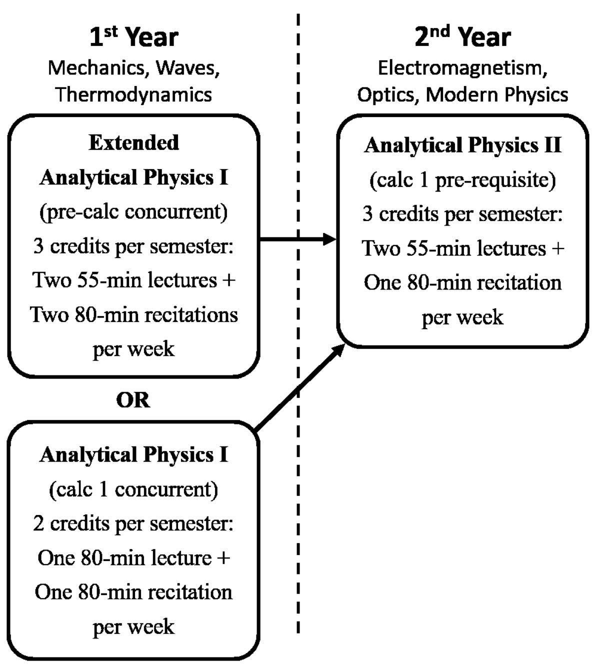

FIG. 1. The two-year Analytical Physics sequence, adapted from Ref. [56].

In the first year, the EAP1 and AP1 parallel courses differ most primarily by students' math preparation: those with average or high math placement scores are encouraged to enroll in AP1 with concurrent placement in Calculus 1, whereas those with low math placement scores are encouraged to enroll in EAP1 with concurrent placement in pre-calculus. Both first-semester courses of this sequence primarily enroll first-year students, and while advisors encourage students to select the appropriate course based on the students' math preparation and math placement score, students may ultimately choose whichever course they prefer. The EAP1 course has the same curriculum and weekly pace as the AP1 course, and both courses have the expectation of calculus-based physics development. However, the EAP1 has twice as many weekly meetings (two lectures, two active-learning recitations compared with one lecture and one recitation), smaller recitation sizes (18 students per section for EAP1 compared to 24 for AP1), and has a greater emphasis on math development within the physics context to guide students' pre-calculus and calculus development. In the second year, students from both EAP1 and AP1 continue to AP2, with AP2 being the same design as AP1, and all students are expected to have at least completed Calculus 1 before they enter the second year.

For the Fall 2018 semester, the recitation materials for all courses in the sequence were of the same design intentions [57]; however, the EAP1 course had two recitations per week and so each recitation had additional questions and tasks which went deeper into conceptual and mathematical development than AP1. Active learning recitation facilitation expectations and student engagement expectations were the same for all courses in the sequence: students worked in groups of 2 to 3 on provided materials while instructors roamed, answered questions, and engaged students in discussion. The lecture designs were also largely the same: students engaged via polling questions dispersed between 10 and 20 min periods of lecturing, with demonstrations interspersed as needed. AP1 and AP2 had the same textbook, but EAP1 had a different book. All courses had weekly online homework (automatically graded, instant binary feedback) with similar expectations and style of questions, and AP1 and AP2 used the same homework system (Mastering Physics [58]), but EAP1 differed in their homework system (WebAssign [59]). The learning management system used in all courses (Sakai [60]) served as a means to distribute lecture notes and announcements; however, there were no learning activities conducted within the management system. For example, all recitations, lectures, homework, quizzes, exams, and surveys were done outside of the learning management system. Furthermore, EAP1 was led by a single physics education research who does not rotate out of that role, whereas AP1 and AP2 were led by a pair of research faculty and/or teaching faculty who rotate out every 2 to 3 years.

EAP1 had 91 study participants, 139 total enrollment, and a response rate of 65%. AP1 had 427 study participants, 785 total enrollment, and a response rate of 54%. Finally, AP2 had 151 study participants, 603 total enrollment, and a response rate of 25%. The latter response rate was low due to logistical issues associated with time constraints and a lack of advertising of the study in that course compared with the other two courses. Students were provided with a description of the study as well as informed consent both in an email announcement as well as in the first question of the survey. Students had the option within the survey to choose to have their data included in the study; the researcher removed the data of those students who answered "no" to this question prior to analysis. Students were able to take the survey from any computer or capable mobile device during the time the survey was open. All students had the opportunity to participate in the survey for course credit, where credit was given for attempting the survey regardless of whether students chose to include their data in the study. The course credit amount ranged from 1% to 2% of their total course grade and was not given as extra credit. In this situation, a student who did not want their data included in the study but attempted to respond to the survey earned the full course credit associated with responding to the survey questions; course credit was not in any way associated with the student's choice to include their data in the study. For the full list of online survey questions, see Appendix A. The lists of response options in survey questions 1 and 4 involving textbook usage mode and common online resources, respectively, were initially generated via a brainstorming discussion with undergraduate learning assistants [61] and graduate teaching assistants involved in the courses, and then implemented via a pilot survey in the Spring 2018 semester. Based on feedback from the pilot survey, adjustments and inclusions were made to create the Fall 2018 version shown in Appendix A.

B. Interviews

I followed a phenomenographic framework for the interviews and aimed to describe the ways a group of people understand and experience a phenomenon [54,62]. This was done by capturing the essence of students' experiences with course and online resources via a semistructured interview protocol. Through these interviews I captured students' perceptions of course resources, course tasks, and common online resources used in their course approach. To analyze the interviews, I followed a phenomenographic analysis procedure by extracting emergent patterns in students' responses to the interview questions about their approach to textbook and online resource usage. These patterns formed the basis of categories, and within each category are subcategories of student responses as needed to describe and distinguish unique student experience patterns with the course and online resources.

To populate the pool of potential interviewees, the last question in the online survey asked students about their interest in participating in a follow-up interview about their survey responses. This question stated, "Are you willing to volunteer to be interviewed about your responses to the previous survey questions on textbook and online resource usage?" with "yes" or "no" response options. There were 319 interview volunteers, which corresponds to a response rate of about 21% of the 1527 total enrollment for all three courses combined. Students who responded yes were entered into a pool from which a subset of students were randomly selected to participate in individual in-person interviews led by Ruggieri who had no affiliation with the course leadership, logistics, or grading practices during the semester for which data were collected. Selection of the interview participants was done through stratified random sampling from this pool with gender as the stratification criteria, as well as limiting interviews to only include students from AP1 or AP2. Focusing on the AP1 and AP2 courses for interviews was a practical choice: AP1 and AP2 have not had updates to materials and practices for several years, end-of-semester survey responses are generally less favorable than EAP1; AP1 and AP2 have a greater fraction of academic integrity issues in homework and exams than EAP1, and, as is discussed in Sec. IV, a disproportionately greater fraction of students reported using Chegg in AP1 and AP2. In total, there were $N_I = 11$ interview participants: 7 female and 4 male, nine of which were from AP1 and two from AP2. I opted to cease interviews after 11 participants because saturation of interviewee responses was observed, as evidenced by repeat responses and a lack of unique responses to the interview protocol in the last several interviews.

Interviews were audio recorded (no video) and lasted 30–60 min, during which students responded to open questions about their survey responses and elaborated on the factors surrounding their responses. I followed a semistructured interview methodology by which an interview protocol was developed and employed, and I deviated from the protocol as needed to more deeply explore students' responses to a given question. For the full interview protocol, see Appendix B.

After interviews were completed, the interviews were transcribed using a transcription service [63]. Interview transcriptions were analyzed in a series of steps using NVivo analysis software [64]. First, broad patterns in responses were identified as primary categories using an emergent coding methodology; this process was started as the interviews were taking place. Second, transcriptions were revisited using the initial list of broad categories as a guide to bin interview excerpts, resulting in more categories added when interview excerpts were not adequately described by this first set of emergent categories. Categories were separated into more specific subcategories when utterances were of sufficient specificity to permit such distinctions. Alternatively, two or more categories were consolidated into a parent category if utterances were not sufficiently specific to distinguish between those categories. In this way, I arrived at a list of emergent categories and subcategories which represent the patterns in students' utterances regarding the phenomenon of resource use in their physics course. The results discussed in this study represent a subset of the total interview protocol questions, specifically, "Part 2: Online survey follow-up questions" of the interview protocol, though I provide the full protocol in Appendix B for reference. All names associated with interview excerpts are pseudonyms.

IV. RESULTS

A. Surveys

Students were first asked about their mode of textbook usage given several options (selecting all choices that applied), as shown in Fig. 2. This list of textbook modes was populated via a brainstorming session with course learning assistants and graduate teaching assistants in Spring 2018, then implemented as a pilot survey at the end of the Spring 2018 semester and further refined for the survey in this study. Because of similarities in textbook purchasing options and course expectations for textbook use, results for choice of textbook mode from all three courses are binned together. About 48.8% of students reported purchasing the interactive electronic textbook, 13.5% purchased a new paper textbook, 6.9% borrowed another person's book, 3.0% purchased a used book, 1.9% rented the book, and just 0.3% obtained a copy from the library. A sizable fraction of respondents, 11.3%, reported not obtaining any form of textbook whatsoever. A small fraction of students reported using the OpenStax University Physics free online textbook [65] because it was listed in one course's syllabus as an optional free alternative to the recommended traditional textbook. The low reported usage of OpenStax was likely due to lack of advertisement by the course leadership, as well as the recommended text or e-text being paired with online homework system access at relatively low cost, and students using OpenStax needed to purchase separate homework access at similar cost to the e-text pairing. A small fraction of students also report textbook readings being provided by the course because in EAP1 excerpts from a supplemental book were freely distributed to students, or perhaps students may have conflated using the free OpenStax book with this response option. Within the "other" category representing 5.1% of respondents, excluding the responses that reiterated given options, students reported illegally downloading a digital form of the book online for free, or the paper textbook was provided by the New Jersey Educational Opportunity Fund (EOF) program which provides financial assistance for students from disadvantaged backgrounds [66]. Thus the provided list of textbook usage options appears to be fairly comprehensive.

Students were then asked how textbook cost influenced their choice of textbook mode, as shown in Fig. 3. Again, the three courses were binned together due to similarities in textbook purchasing options and course expectations for textbook use. About half of the respondents (56%) reported textbook cost as "very important" in their textbook mode choices, and 31% report textbook cost being "somewhat important" in their choice in textbook usage, for a total of 87% reporting that textbook cost had some influence over their textbook choice. Only 13% of respondents reported that textbook cost was "not important" at all in their decision.

To conclude the survey section on textbook usage, students were asked how often they used the course textbook given the following frequency scale within the context of a 15-week semester: "often" (1–2 times per week), "occasionally" (1–2 times per month), "rarely" (1–2 times per semester) and "never." Students' responses were consolidated into two bins, frequently used (often and occasional) and infrequently used (rare and never) represented in Fig. 4 as gray and blue bars, respectively. Students in EAP1 had the least fraction of frequent textbook users (30%), followed by AP1 (47%), and, finally, AP2 had the

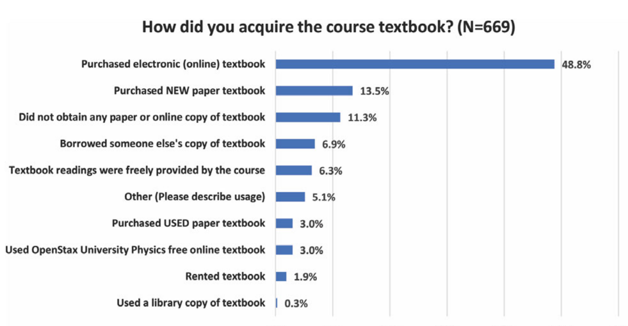

FIG. 2. Students' reported textbook usage mode in EAP1, AP1, and AP2 combined.

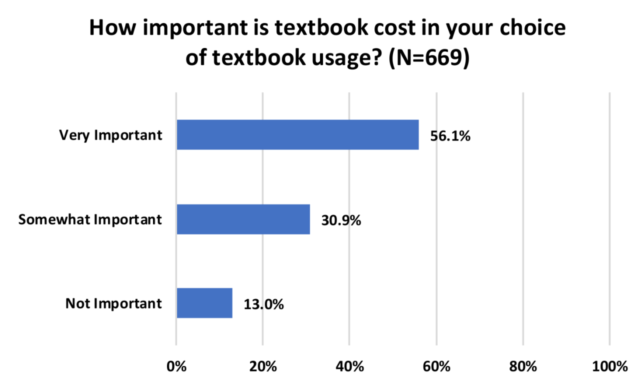

FIG. 3. Students' reported consideration of textbook cost when choosing a mode of textbook usage in their introductory physics course. Results from EAP1, AP1, and AP2 are combined in this figure.

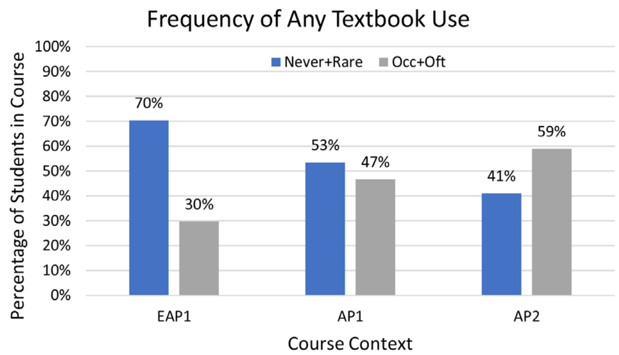

FIG. 4. Students' reported textbook usage frequency by course ($N_{\mathrm{EAP1}} = 91$, $N_{\mathrm{AP1}} = 427$, $N_{\mathrm{AP2}} = 151$).

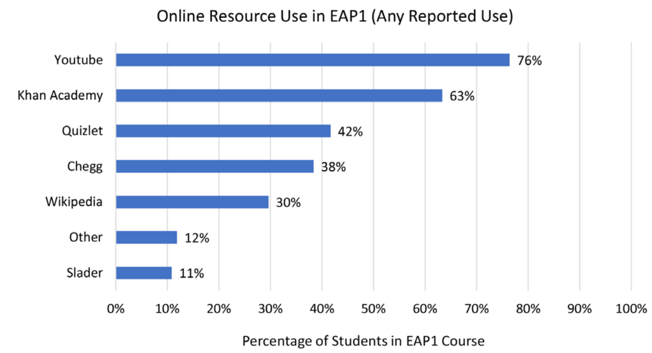

FIG. 6. Percentage of students in Extended Analytical Physics 1 who reported any use of a given online resource ($N_{\mathrm{EAP1}} = 91$).

greatest fraction of frequent textbook users (59%). These results include the students who responded that they did not obtain any copy of the textbook. The textbook is incorporated into each course similarly: a syllabus listed the textbook sections for each unit but there were no course activities which explicitly required use of the textbook. Anecdotally, during my time as a former leader of EAP1 in the 2016–2017 and 2017–2018 academic years (not the semester surveyed here), returning learning assistants mentioned no need of the textbook because the course meetings and resources sufficed to succeed in the in-class activities and course assessments. However, learning assistants are generally high-performing students and do not represent the views of the entire EAP1 population.

When students were asked about their usage frequency of any online resources, shown in Fig. 5, the vast majority of respondents in each course reported frequently using online resources: 88% of EAP1 students, 92% of AP1 students, and 97% of AP2 students. While many students tend to not frequently use the textbook, almost all students surveyed in each course context frequently use online resources, pointing to the prevalence of online resources in students' course approach.

To explore students' usage of online resources in more detail I included a subsequent question which asked students to report their usage of several common online resources, as shown in Fig. 6 for EAP1, Fig. 7 for AP1, and Fig. 8 for AP2. This list of resources was populated via a brainstorming session with course learning assistants and graduate teaching assistants in Spring 2018, then implemented as a pilot survey at the end of the Spring 2018 semester and further refined for the survey in this study. The data are organized in order of reported use among students in a given course. In all three courses the most prevalent resources were YouTube and Khan Academy. YouTube is a popular media outlet hosting a wide variety of

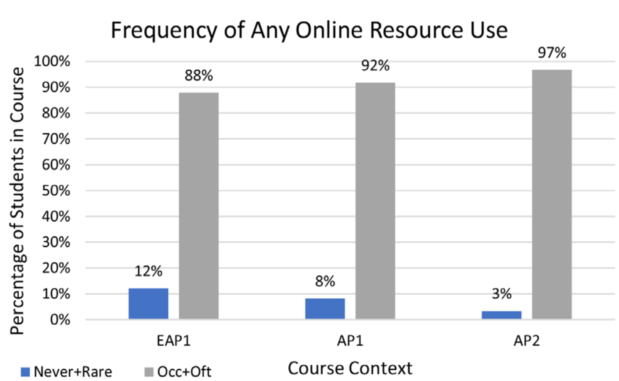

FIG. 5. Students' reported usage frequency of any online resources by course ($N_{\mathrm{EAP1}} = 91$, $N_{\mathrm{AP1}} = 427$, $N_{\mathrm{AP2}} = 151$).

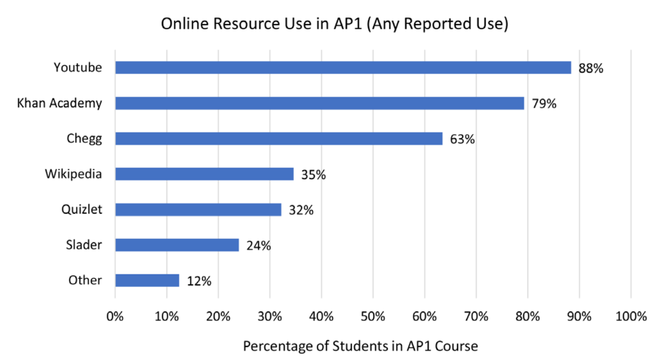

FIG. 7. Percentage of students in Analytical Physics 1 who reported any use of a given online resource ($N_{\mathrm{AP1}} = 427$).

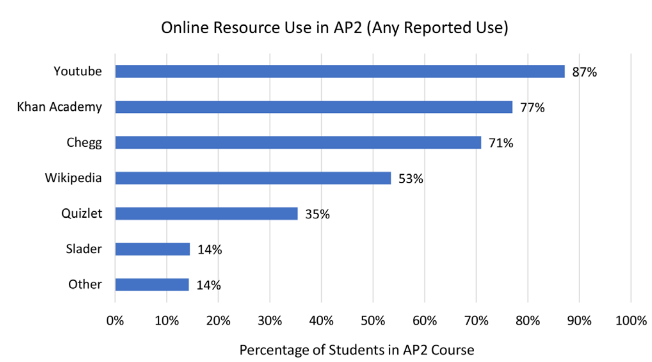

FIG. 8. Percentage of students in Analytical Physics 2 who reported any use of a given online resource ($N_{\mathrm{AP2}} = 151$).

user-generated content, including educational videos, and there is no review or filtering process of uploaded content except for user agreement constraints such as copyright infringement. YouTube was the most popular online resource in all three courses with reported use by 76% of students in EAP1, 88% of students in AP1, and 87% of students in AP2. Khan Academy hosts solely education videos generated by Khan Academy educators and is designed specifically as a free online educational resource. Khan Academy was the second most popular resource in each course with reported use by 63% of students in EAP1, 79% of students in AP1, and 77% of students in AP2.

The remaining resources were used by significant fractions of students in each course, but were less popular overall than YouTube and Khan Academy. Chegg is a subscription-based website repository of textbook solutions, with solutions submitted by other users or by Chegg "experts," and the $14.95 USD per month subscription fee includes online tutoring with a Chegg tutor. Chegg was the third most popular online resource in AP1 and AP2 with reported use by 63% and 71% of students, respectively, but only 38% of EAP1 students reported its use. Quizlet offers free flashcard activities, games, and other online learning tools for foundational knowledge in a given subject, and also hosts premium content generated by Quizlet educators for a fee, such as study guides for common standardized exams. Quizlet was reportedly used by 42% of EAP1 students, 32% of AP1 students, and 35% of AP2 students. Wikipedia, a free online encyclopedia that relies on public uploads and public editing of the content, was used by 30% of EAP1 students, 35% of AP1 students, and 53% of AP2 students. Finally, Slader is similar to Chegg in that it hosts user-generated step-by-step textbook solutions with available subscriptions to premium content, and was far less popular than Chegg across all courses with reported use by just 11% of EAP1 students, 24% of AP1 students, and 14% of AP2 students.

The other category was given as a catch-all for resources missing from the given list. The given list of online resources appears fairly comprehensive as there were just 33 total responses and 12 unique resources across all courses within the other category that differed from the given resource list, with the number of students reporting the resource given in parentheses: Google or Bing search engines for general searching (12), Yahoo Answers (9), HyperPhysics (3), Reddit (1), Quora (1), CourseHero (1), ProPrep (1), CrashCourse (1), Twitch.tv (1), Physics Forums (1), Feynman lectures (1), Wolfram Alpha (1). These little-used resources are reported here for completeness, however descriptions of each of these resources is left to the reader to investigate.

I also explored the number of unique online resources that students reported using, shown as Fig. 9 with responses for all courses combined. Most students used three unique resources (29%), followed by two or four resources (approximately 20% each), then one or five resources (9% each), six resources (7%), and finally no online resources used (5%).

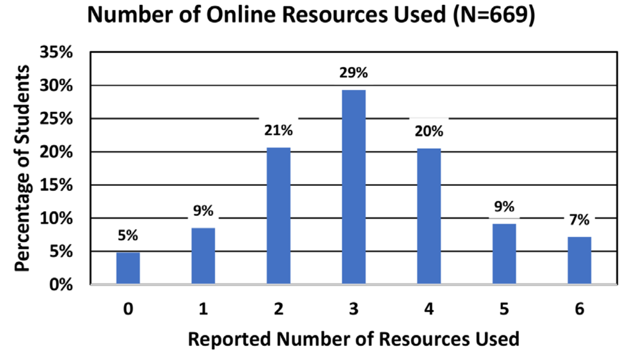

FIG. 9. Number of unique online resources reportedly used by each student. Results were combined across all three courses.

I then explored students' usage frequency for individual online resources, excluding the other category, on the same scale of often, occasionally, rarely, and never. Focusing on only those students who reported using a given resource, the fraction of student users who report relatively frequent use (often or occasional) is shown as Fig. 10 for EAP1, Fig. 11 for AP1, and Fig. 12 for AP2. This dataset includes only those students who reported any use of a resource; those who reported Never using a given resource are not included. For example, 75% of YouTube users in EAP1 reported frequently using that resource, whereas 88% of YouTube users in AP1 reported frequently using it. From this view of the data, it is evident that students who report using YouTube, Khan Academy, and Chegg use them more frequently than the remaining resources. As such, for the rest of this study I focus on the most widely and frequently used resources in the survey: YouTube, Khan Academy, and Chegg.

As described in the Methods section, AP1 and AP2 are quite similar in learning context, whereas EAP1 has more contact time and course activities per week, fewer students

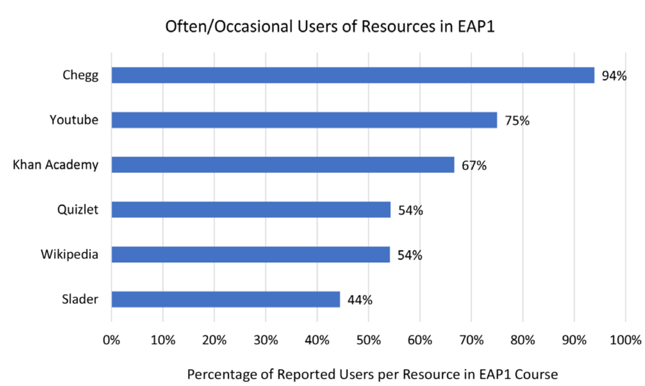

FIG. 10. Percentage of resource users who reported often or occasional usage frequency of that resource in Extended Analytical Physics 1 ($N_{\mathrm{EAP1}} = 91$).

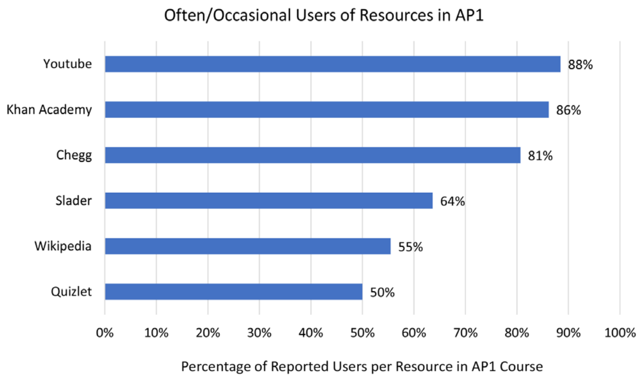

FIG. 11. Percentage of resource users who reported often or occasional usage frequency of that resource in Analytical Physics 1 ($N_{AP1} = 427$).

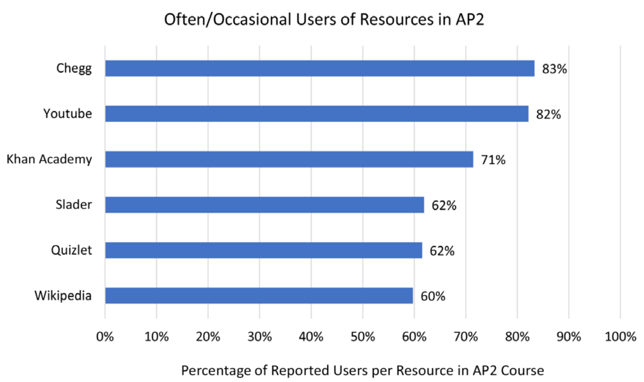

FIG. 12. Percentage of resource users who reported often or occasional usage frequency of that resource in Analytical Physics 2 ($N_{AP2} = 151$).

per recitation section, and is led by a physics education researcher who is familiar with and regularly implements evidence-based instruction practices. Students across all three courses reported comparably frequent use of any online resources, as shown in Fig. 5. However, when looking in detail at the fraction of students in each course who used YouTube, Khan Academy, and Chegg from Fig. 6 for EAP1, Fig. 7 for AP1, and Fig. 8 for AP2, several observations distinguish AP1 and AP2 from EAP1. First, a similar fraction of students in AP1 and AP2 reported using YouTube (88% and 87%, respectively), whereas a slightly lower fraction of students in EAP1 reported its use (76%). Second, the fraction of students who reported using Khan Academy is greatest in AP1 (79%), followed by AP2 (77%), and then least in EAP1 (63%). Finally and most interestingly, a disproportionately greater fraction of students reported use of Chegg in AP1 (63%) and AP2 (71%) compared to EAP1 (38%). From the perspective taken in this study that course resource deficiencies may have drove students to use outside resources, this observation in AP1 and AP2 of disproportionately greater use of Chegg, greater use of YouTube and Khan Academy, and other contextual factors discussed in Sec. III motivated the decision to conduct follow-up interviews with students from AP1 and AP2 and further explore their responses to the survey questions.

B. Interviews and categories

During the interviews, students were asked to elaborate on their survey responses for usage frequency, usage habits, and purpose of each online resource they used, as well as for their chosen textbook and course-provided or University-provided resources such as office hours and Learning Centers. Interview transcript analysis resulted in several emergent categories which are presented in Table I. Main categories are presented in bold font, below which are listed subcategories and associated descriptions.

Our courses employed a weekly cycle starting with lecture, followed by active-learning recitation, and

TABLE I. Interview coding themes.

Category	Description
1. Resource purpose	**Ways in which students used the resource: T = Text or e-Text, O = Online Resource**
Explain or clarify	Read or view for foundational knowledge of a topic. (T + O)
Summary of key points	Read text to summarize main topics for a unit. (T)
Guided practice	Use guided solutions for line-by-line problem solving steps. (T + O)
Extra problems	Additional questions used for self-practice. (T + O)
Confirm answer or copy solutions	Use resource to validate approach to a problem or to achieve high grades on the task. (O)
2. Homework process	**Process by which students complete a homework task.**
Learning focus	Use a resource to deeply engage in learning of the concepts.
Task completion focus	Search resources to find answers to a task, generally without attempting to learn.
3. Barriers	**Obstacles to resource use and learning experiences.**
Textbook usage	Textbook features or course factors that prevent students' textbook usage.
In-person resources	Factors that lead students to seek alternatives to course- and University-provided in-person resources.
Learning engagement	Descriptions of course structure, expectations, or resources which present obstacles to students' learning experiences.

culminating in an individual online homework activity. Students reported using various resources throughout the weekly cycle such as before lecture or recitation to prepare and after lecture or recitation to clarify a concept; however, the most popular time during which students engaged with resources was when they were completing the weekly online homework or when studying for an exam. As such, the interviews explored deeply how a student would approach a difficult homework problem: what steps would they take after first reading a problem, what resources would they use and in what order, and how they would hypothetically approach a particularly difficult homework struggle. It was within this line of questioning that students most clearly articulated when and how they used a given resource for the course. I describe each transcript analysis category and associated subcategories in more detail below in the following order: 1. Resource purpose, 2. Homework process, and 3. Barriers.

Within the resource purpose category in Table I, those purposes reported for the text or e-text resource are labeled by "T," whereas those purposes reported for an online resource are labeled "O," and if both types of resources were used for that purpose it is labeled "T+O," Note that I did not apply this labeling to the other categories, homework process and barriers, because in most cases both resource types are mentioned, except for "textbook usage" within the barriers category as it is focused solely on text or e-text use.

1. Resource purpose

Students are faced with a plethora of resources including course-provided materials such as lecture notes, annotated or guided solutions to select core problems, and the course textbook, as well as freely available online resources ranging from introductory educational videos to fully worked-out solutions for most (if not all) textbook problems. The interviewees described several purposes for such resources, given in Table I, and representative examples for each purpose are given and discussed below. In the quotes below, students' utterances regarding a general (unspecified) online resource correspond to YouTube, Khan Academy, and/or Chegg, as these were the main three resources focused on in the interview.

Explain or clarify: Students looked to both textbook and online resources for additional explanations and clarifications of concepts beyond what was presented in lectures or addressed within the recitation activities. Students also voiced a need for alternative representations of content which emphasizes the importance of employing a variety of course activities and resources to support our highly diverse student population.

Textbooks:

> *Brian: Either before or right after a lecture I like to read through the chapter just to make sure that I kind of hit on every topic that's being talked about.*

> *Linda: When I didn't understand the concept, like what is gravitational potential energy? So I would just go online and look at the textbook, and see their explanation of what it is. And if I need an explanation about something, I would go to the textbook occasionally to find the explanation.*

> *Michele: Sometimes in lectures the professor might not expand fully on the concept, and then you can just go into the textbook and look at it.*

Online resource:

> *Leigh: I'm also a very visual learner, so I watch a lot of YouTube videos in that sense just sometimes draw things out. I like to see it pan out, and I feel like the textbook for physics doesn't provide that.*

> *Colleen: I use YouTube videos as well […] I just looked up the topics through YouTube, and then they would have a lot of videos on that. So different channels would explain things differently, and I just picked whatever I liked.*

> *Linda: Sometimes maybe I don't understand something or I forgot something, then I will go to the videos and then they would lecture it to me again in a different way […] I would go and watch videos more so for clarification.*

> *Jess: [Khan Academy] went through every section that we've been learning. Khan Academy teaches foundation. That's what it's made for. It's made to teach people things. So it's great to get a foundation from Khan Academy and then apply it to what we're learning now.*

Summary of key points: Students described using the textbook to find summaries of key points and concise equation lists for a given unit in the textbook, but none described using online resources for this purpose:

> *Colleen: I usually use [textbooks] before the exam just to refresh all the topics again, go through each chapter by chapter, make sure I understand the equations and where they're coming from.*

> *Leigh: For review, I would say before a quiz or an exam. But also if I'm just preparing to study in advance, I'll use [the textbook] to outline.*

> *Michele: I don't find [the textbook] very helpful. There's a section at the end of each chapter, I guess, for key ideas and I would just look at those and then I would try to use other resources.*

Guided practice: Students frequently spoke of searching for line-by-line solutions, solutions with annotations, or verbal guidance explaining why each step was taken. They used both textbooks and online resources for this purpose; however, they more frequently mentioned using online resources for such guided practice. This preference for online resources as guided practice is reasonable given that a textbook section might have only one guided problem example whereas online resources have many more available in both written and video form.

Textbook:

Jess: I look up a different way to solve a question. And the textbook commonly has a different way of doing it that might be more understandable to me, sometimes not.

Leigh: I'll read the chapter. I'll outline. And then when I'm given a solution with the problem, so I can make sure I'm doing it the right way and I'm getting the right answer so I'm not just left in limbo. So if they had worked-out solutions, I would look at those so I can make sure I'm following the right steps.

Online resource:

Jess: There was one guy that posted videos [on YouTube] of questions and explained the background to the question and how to solve it. So I'd watch those videos to complete my homework. I copy and paste the question, and I put it into the search bar and I click Search. I find the one that usually has an expert answer and that gives you word-for-word explanation about how to get your solution and shows you all the equations to use.

Michele: I usually just use [YouTube and Khan Academy] for the same purposes. It's just whichever one has a better video. And also, the videos would walk you through the process of how to do it. So that was really helpful.

Extra problems: Students reported a need for practicing problems similar to ones they saw in the course lectures, homework, or practice exams as a means to study for an upcoming exam. Students did report using both the textbook and online resources for finding extra practice problems, though online resources were the more popular choice for this task.

Textbook:

Colleen: I would read notes or look at problems and complete them. And then there's usually odd answers in the back, so I would compare my answers to that. Also just making sure that I get [that] concept correct.

Online resource:

Gil: I got used to just looking through Khan Academy, either for extra practice or to really get another perspective, on how to… I don't know… integrate something, or find the volume of a curve, to get to know how to better answer an archetypal question and just truly understand it better.

Michele: It's usually when I can't figure out–when I don't understand a specific concept […] and I'm not 100% confident on how to do it, so I would search up similar questions to that question online to get more practice.

Confirm answers or copy solutions: Particularly when engaging in homework, students reported searching online resources for line-by-line solutions to confirm their process or approach after they made an attempt at the problem. However, students also regularly reported using the same online resources with the intention of copying the work if the problem presented too high of a barrier to solve. In the confirm answers category, the intention communicated by the students was to check if their homework attempt was on the right track, and to assess their approach, adapt, and learn. Whereas in the copy solutions category, the intent was to mitigate homework point loss and gain credit without engaging in learning, either by choosing not to attempt the problem at all (for example, due to time constraints), or when encountering a barrier too high to complete the problem.

Students conveyed a use of Chegg for confirming their approach, and hint at guided solutions as a valuable resource for confirming their process, for example, as Karen stated below:

Karen: [Chegg] gives you solutions, and I found out that coming [to this University], not a lot of teachers give you solutions. So you can't check your answers against it.

On the other hand, Jess communicated her approach more in line with a purely copy solutions intention:

Jess: I find the one that usually has an expert answer and that gives you word-for-word explanation about how to get your solution and shows you all the equations to use. And then, usually, Chegg doesn't have my question number for number. Might have it word for word, so I have to use my own values, plug it into the equation.

Some students expressed notions of the utility of online solutions while also noting verbatim copying of solutions as potentially unhelpful to learning, for example, as Karen stated,

Karen: [Online solutions] help you because they don't have the same numbers, obviously, all the time. So you have to figure it out yourself, how the formula is ordered, how you're supposed to–it's not just plugging in your numbers, you have to figure out how they got there so you could redo it later.

Furthermore, Leigh elaborated on the struggle between choosing to copy solutions for credit versus choosing to engage in learning more meaningfully,

Leigh: It's all about your intention too. If you're going in to get the right answer on a problem, it could hurt you because then you're just mindlessly doing it, plugging and chugging. But if your intention is to learn, I definitely think it helps. Chegg gives you a lot of power to just get the right answer. So if you're actually trying to understand it, it helps a lot. But it can also hurt you if you don't have the right intention.

In total, students' reported resource purposes suggest that online resources were used for a greater breadth of purposes than any form of textbook. Online resources served purposes traditionally satisfied by a textbook, such as extra problems and guided practice via example problems. The only unique textbook purpose reported by students was to summarize key points in a chapter. Importantly and more generally, these results elucidate the ways in which online resources are replacing textbooks as a study tool in our course context.

2. Homework process

This juxtaposition of homework approaches exemplified by Leigh's quote in the prior section, mitigating credit loss versus engaging in learning, motivated a more detailed exploration of students' decision making processes during homework assignments. I asked students, hypothetically, how they would approach a particularly difficult homework problem that they could not complete from their existing understanding of the concepts. Students elaborated on their approach to such a hypothetical situation, for example,

Serge: What I usually do is I […] do the question and […] if I get it right, I get it right, go on to the next one. But if I don't get it right, I keep trying to see what I did wrong, and if I still don't get it and I'm approaching like two more chances… I go to Chegg. I see how they did it. I do the equation myself. Even if it's the same answer, I do the equation myself just so that I can comprehend… And I only literally Chegg it in the same way of putting in the answer and everything if I have absolutely no idea what to do, you know?

Leigh: So I'll watch a YouTube video and see if they have a sample problem. And then if I can't find a problem similar to that or similar enough to where it covers the same concept and it doesn't help me, then I'll go into Chegg and see if they have a worked-out solution. And if they do and I'm reading it and I get confused by that, then that's where I'll go to a TA or something afterwards, but I will use that solution for the time being just to get it done… and then I'd be like, "Oh, my God. There's 12 questions. I got to keep going." Because you want to see all the material. But it's so hard. Sometimes, when you're put in that situation, it's just inevitable.

Gil: I would open up the lecture notes just to see–so the lecture notes would usually give you all the equations you need to use… I read them first, just to familiarize myself… I tried that and it didn't work so then I said there's something else going on here. And then I went to Khan Academy to see if anything would be helpful. And there were other [examples] … but there wasn't the exact scenario on Khan Academy… so then I looked it up on YouTube and I found something. And the equations there were pretty useful. It kind of skipped around a little bit, and I wanted a more detailed explanation. So then I went to Chegg and see what

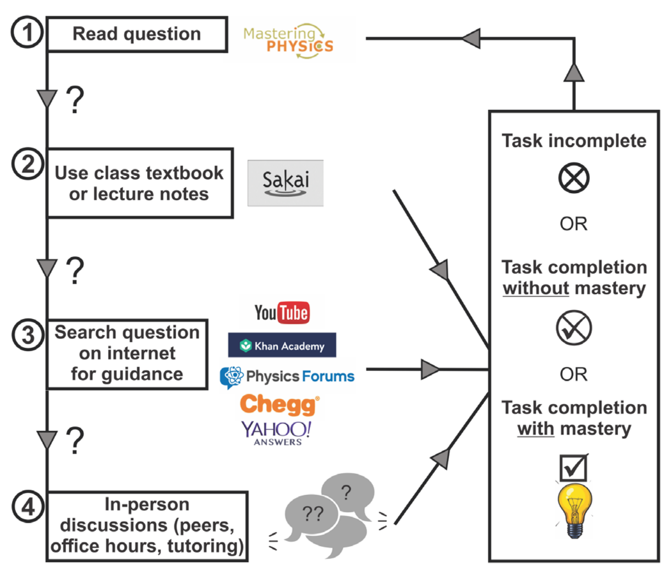

FIG. 13. Patterns of students' homework process for a given question, extracted from interviews ($N = 11$). Students (i) read the question, (ii) look to course materials for help, (iii) use online resources, and (iv) seek in-person help. Question marks represent students' persistent confusion which drove them to use the next resource. At any point in during Steps (ii)–(iv) students may choose to leave the task incomplete, seek solutions to finish the task without engaging in learning, or strive to learn while completing the task before moving on to the next question and repeating the cycle.

they did. And I compared it, contrasted the differences and they were about the same and that helped.

The patterns in students' reported resource engagement during homework are presented as Fig. 13. First, students read the question on the homework management system associated with their course, in this case Pearson Mastering Physics for AP1 and AP2. If they were unsure how to solve the problem, they then oriented themselves by looking through the course-provided lecture notes, or, to a lesser extent, the course textbook for relevant equations, definitions of terms, and simple applications. If they were still unsure and were unable to solve from course-provided materials, they searched the internet for guidance typically by typing part or all of the question into their preferred search engine. In this third stage, students engaged with videos, line-by-line solutions, and forums to either gain knowledge on the concepts and process, or search for solutions to copy. Finally, if after using the internet they still were unable to solve, some students used in-person resources as a last resort. The most frequently reported in-person resource was discussing with close-proximity peers, and to a lesser extent going to an instructor's office hours or drop-in tutoring at the University Learning Centers. At any point in this homework process after reading the question, students chose to either leave the task incomplete and get no credit, complete the task without gaining any mastery by copying solutions and circumventing their learning, or complete the task with mastery by using the resources productively to gain deeper understanding of the concepts, before moving on to the next question and repeating the cycle.

These patterns in homework approach are similar to studies in physics and in chemistry courses on students' homework process. One study in introductory physics ($N_{\mathrm{male}} = 97$, $N_{\mathrm{female}} = 138$) showed that the majority of students' first step in an online homework process is either immediately attempting a solution (58% of males, 39% of females) or reading up on the topic (34% of males, 41% of females), with comparatively few students initially seeking instructor or peer resources (8% of males, 20% of females) [46]. A study in a general chemistry course asked students ($N = 175$) what they do after incorrectly answering an online homework question, then extracted the following patterns in students' responses: 69% sought help from print or online source, 34% reworked the problem and checked for mistakes, and 26% sought help from a person [42]. Of the 26% of students who sought help from a person, 16% sought help from a peer or friend, 5% from the professor, and 3% from the chemistry learning center. Our results are similar in that students preferred to use course and online resources to address struggles first, and comparatively few used any in-person resources unless the course and online resources were insufficient. Additionally, when in-person resources were used, students preferred discussing with friends or peers over office hours and Learning Centers.

Many students reported never using an in-person resource and instead simply looked up solutions to copy to prevent loss of points. That is, they stopped at step 3 in Fig. 13 and never arrived at step 4 (for reasons discussed below in the Barriers section). Chegg is the primary online resource for such a purpose, and when discussing their homework process every student I interviewed communicated some usage of Chegg in their physics homework approach. Students also had keen awareness of how their peers use Chegg for homework even if they did not use it frequently themselves. Students alluded to the struggle between (a) using Chegg to copy solutions and get credit without meaningful learning, and (b) using the solutions to reverse-engineer the process and learn. The homework assignment was typically opened one week before it was due, which students admitted was plenty of time for the task. Their choice to engage with online resources to learn versus copying solutions for credit was influenced significantly by how much time they left themselves to complete the homework, as determined by their individual scheduling and planning. Specifically, students reported that they or their peers were more likely to resort to Chegg for copying solutions or just giving up altogether if time was running out:

Serge: I had a meeting earlier that day that I didn't expect to take long. I had to go to my professor's office hours… one of the buses took forever for whatever reason so my entire plans got shifted. So I went [to office hours] and I knocked out a lot of the questions, understanding it, doing it. Then there are three problems left and I looked at one of them like, "I know I could do this if I had more time." But I couldn't and yeah, that deadline definitely made me rush it. The timing definitely has a massive effect.

Michele: Usually people would use [Chegg] when they're pressed on time because they kept pushing it back. They procrastinate on their homework, and then it's like Wednesday night, and they have like an hour to do it, so then they would just search up the questions…

Karen: Sometimes it's not worth finding the solution if you're on a time crunch, so you just get zeroes and you have to move on to your next assignment that's worth more weight on your grade.

students' homework processes, choices of resources, and choices of how to engage with a given resource were generally influenced by barriers they experienced during that process. For example, as noted above by Serge, Michele, and Karen, time and time management critically influenced students' homework engagement and process. Students voiced several barriers to their engagement in learning besides time, which in some cases drove them to task completion focus and abandoning learning. In the following Sec. I report students' elaborations of such barriers to resources and their learning experiences.

3. Barriers

When I asked students about their homework process and the resources they used, most students elaborated on various barriers to engaging with the course-provided materials and course- or University-provided in-person resources, as well as barriers to their learning experiences. Exploring student-reported barriers to engagement will inform future changes in teaching practices to lower or eliminate those barriers and consequently improve learning experiences for students in our courses. Below I report three primary categories of barriers which students voiced (given in Table I), in the following order: Textbook usage, in-person resources, and learning engagement.

Textbook usage barriers: Students reported struggles with using any form of textbook in that the textbook was not well incorporated into the course structure and they did not need to use it as a resource to complete the required course assignments:

Leigh: It was never required to use it. [The professor] didn't mention it. Before exams, it was like, "Make sure you read the textbook in case I didn't cover it in class or something." But I found that you didn't have to. [The professor] covered mostly everything on the exams.

Karen: We never had to reference it during a class or… we didn't take problems from that for the recitation either. It was just for like the homework.

Serge: I think literally the only time the book was mentioned at all by the overall course was this one question on mastering physics where it said, "Look to the book, page blah blah blah blah if you need help," and I'm like, "Oh well, I don't have that page and I have an older edition so it might not even be that page."

Gil: I feel that I didn't even need [the textbook], really. I could have used something else to get that same information since the only reference to the textbook in the entire course that I can recall was in the […] course schedule.

It is worth noting that textbook cost did influence students' choice of textbook mode, with the e-text being least expensive due to being paired with the online homework access fee, and paper copies of the textbook being the most costly. Students shared their thoughts on interactions with e-texts, generally noting frustration and effort at navigating to specific sections using the web interface and reading in a pdf reader or browser.

Leigh: I like having paper textbooks, but it was just more cost effective to get online textbooks this semester or PDFs or online e-books or something like that. But I like paper version just because it's tangible, and reading online, you have to scroll. So I study more effectively when I have a paper version. But it was just like paper version is 500 [dollars] and your e-book is 18 dollars.

Linda: I thought because the stuff that I saw online were already helping me, then I wouldn't need to go to the textbook. But if I couldn't understand what the online stuff were saying, then I would go to the textbook. Because I also didn't want to fidget around: sign in [to the e-text], and then go to this tab, open this, find the section, find the chapter, and then it's there.

Leigh's quote about the difficulty of scrolling is consistent with prior research on the relationship of text passage length and reading comprehension in printed text versus e-text. A recent meta-analysis suggests comparable reading comprehension between e-text and print for short passages up to a single page, yet longer passage lengths necessitating the act of scrolling in an e-text negatively impacts efficiency of information processing and increases cognitive load due to navigation issues when scrolling [16].

Linda and Michele described the act of finding a relevant section in the e-text taking more steps compared with printed text, and conveyed a preference for printed text for such activities. A recent study on chemistry students' usage of e-text and printed text reported that students liked the e-text for its low cost and ease of searching for a specific term or phrase (via a search feature); however, they reported the printed text as easier to read and annotate, and having fewer distractions [14]. It is not clear how the e-text user interface and features used in our context compares with that of this recent study, and course context (e.g., chemistry or physics) may play an important role in how students perceive and engage with any form of course textbook. For example, several students reported their lack of physics textbook usage as compared with other courses:

Leigh: In [calculus 1] and [general chemistry 1], I would read the textbook through and through. For chemistry, I read every single chapter that I got tested on, and for calc, I also read every single chapter I got tested on. But I didn't use it for physics.

Gil: I feel like for my psychology class it was a worthwhile purchase. I got my money's worth. I read pretty much the whole thing. Whereas in physics I read maybe a total of, I don't know, 50 to 60 pages. I truly felt that I didn't have to buy it. Incoming freshman, had to *buy all my books. I don't know what's going to happen. But if I could go back, I probably wouldn't purchase it.*

Brian: [The physics textbook] didn't go into enough details for me to do problems. The practice problems in the book, I felt they weren't backed up enough by the material they were teaching. It's kind of like being taught how to do addition and then doing calc problems for practice problems… It's really useless compared to other courses. I'll read from other textbooks from my courses and I'll gain some understanding that will help me during exams or just doing practice problems, but not really for physics. [In other courses] the chapters are longer and they go into greater detail in my opinion.

Leigh's report of having used her textbook in chemistry more frequently than in physics is consistent with a recent study on students' use of course resources in a general chemistry course, in which students report relatively frequent textbook use, and using the textbook more frequently than using YouTube [13].

Reported factors which lowered the perceived utility of the physics textbook in students' studying for the course included the text not going into enough detail and not having guided problems matching the level of complexity of the homework. Homework problem sets in our courses tend to have a mix of low complexity foundational problems and high complexity application problems, usually with a greater amount of high complexity problems. When engaging in a high complexity problem, students first looked to course-provided resources for guided practice to bridge the gaps in their understanding; however, these high complexity homework tasks were generally well beyond the complexity of guided examples given in the textbook. For example, Brian and Leigh described a lack of detail in the text:

Brian: [The textbook] didn't go into enough details for me to do problems […] It's kind of like being taught how to do addition and then doing calc problems for practice problems.

Leigh: If [the textbook] had worked-out solutions, I would look at those so I can make sure I'm following the right steps. Sometimes you get the wrong answer, and you're like, "How did I even get here? How is that even possible [laughter]?" And then you just are given no explanation.

In-person resource barriers: A concern faculty frequently voice is why are students not taking advantage of the in-person resources provided by the course and the University, such as office hours and drop-in tutoring? When asked about homework process, students rarely mentioned using in-person resources. I probed further by asking (i) if they use any in-person resources, in what situations they might do so, and (ii) if they don't use them, to describe the reasons or factors influencing that decision. For context, I first present quotes of how students used peers as a resource:

	Barrier	Cause	Impact
Learning Engagement	Assessments value completion of tasks	Homeworks are binary, process is not assessed	Strive for correct answers, lack of focus on process
Learning Engagement	Misalignment of course resources with task complexity and difficulty	Rotating course leaders, pedagogy isn't valued	Seek resources to support learning or get past task
In-person Resources	Proximity to in-person resources (Rutgers' context)	Large school, round-trip travel ~1 hour to in-person resources	Easier to search or talk with peers than to travel
In-person Resources	Schedule conflicts	In-person resources scheduled at popular course times	Students unable to use in-person resources
In-person Resources	Time constraints	Competitive program requirements are demanding on time	Students value efficiency and strategy

FIG. 14. Patterns of student-reported barriers to in-person resources and to more deeply engaging in their learning, extracted from interviews, $N = 11$.

Peers:

Jess: Me and my peers would do homework together every–we'd have a time we'd all meet up and do homework. I usually go to my friends and ask. There's a couple of girls in my hall that don't procrastinate, so I'd usually find them and ask for help.

Leigh: For physics, I didn't go to office hours, but I did study with friends. I have friends from my town that I already knew going into Rutgers. So I got together with them to study for a little bit. But I never went to a formal instructed learning center, office hours or anything.

Michele: We don't meet up. I just do my own thing. If I have a question or if they have a question, we would just text each other or something.

Students found close-proximity peers helpful, yet they spoke of several barriers associated with attending course- or University-provided in-person resources such as office hours. These in-person resource barriers reported by students are listed in Fig. 14 in the lowest three rows: students tended to speak of office hours as an inaccessible resource due to schedule conflicts, time constraints, or travel constraints. Examples of such barriers are given below:

Leigh: […] YouTube does a pretty good job of clearing up some of my confusion, but other than that, it's scheduling and buses. And I live on [Livingston

Campus], so I usually have to come to [Busch Campus], so yeah… I find it helpful when I can talk to my professor for the course because they know what's going on. They're in class with me. They know what they said in class.

Colleen: I did not [go to office hours]. I didn't really know what to ask, in a way, to go to office hours. Before going to office hours, I would like to have an idea of what I have questions about, but I wasn't really–and I didn't think it would help as much. But I should have used the available resources more readily. I just found that it was not as connect–or how do you say it? Personalized. Which is fine, but I thought other resources were… quicker. So I can just look up a YouTube video and understand it on my own pace.

Sarah: [The professor's] office hours came at a time when I had very small amount of time between classes. So I wasn't able to go to [the] office hours.

Leigh noted the benefit of discussing with the course professor, yet she acknowledged travel between campuses as a high barrier to attending such meetings. Interestingly, Colleen communicated that she knew she was struggling with some aspect of the task, but she did not know what to ask or how to formulate the struggle into a cohesive question. Sarah noted a common struggle that although the office hour technically fit her schedule it was infeasible to attend due to general time constraints.

For those who were able to attend office hours, some conveyed concerns that the office hour was not helpful due to how it was led, as Serge and Brian noted in their quotes below:

Serge: I did try going to the office hours but I think [the professor's] office hours were during my Calc 3 lecture so I couldn't go. And he did mention there were the teaching assistant or the recitation people office hours. But if I recall, I looked at their schedules and the only one that was open was a recitation [instructor] who I did not like [… who] was not helpful.

Brian: Most of us didn't go to office hours. Didn't like the professor… The few of us who did go to office hours said some of the professors weren't useful so there was no point.

Furthermore, several students communicated that they would rather spend their limited available time looking at online resources. As Karen succinctly stated,

Karen: We don't visit [office hours] for homework questions because we could just use YouTube and then save our time from going out.

Another in-person resource at the University is drop-in tutoring within our Learning Centers. Whereas office hours are located typically on the campus where the professor or teaching assistants reside, the Learning Centers have locations on each campus to maximize accessibility to students. While some students preferred to study alone, as Michele describes below, others who attended drop-in tutoring cited overcrowding as a barrier, either due to a high flux of students at critical times such as prior to exams, or due to there being too few tutors to manage the students' needs.

Michele: I've heard of [the Learning Centers]. You can do walk-in tutoring or something. But I think I find it better if I study by myself, usually.

Karen: I went [to the Learning Centers] for physics just for the homework, and there's only like 1 guy and there were like 15 kids. So he couldn't obviously spend time to help you go throughout them, so I didn't really go back there.

Jess: I went to tutoring couple times, but they don't have enough tutors… so they gave me like five minutes of help. I mean, you could sign up to get a tutor, but you're not gonna get it because they don't have enough.

Colleen: Sometimes [the Learning Centers] would be [crowded]. I think before exams it'd be packed. But sometimes it wasn't. I went recently, and there was no one there, so it was nice to have that–basically, it was like one-on-one tutoring.

Colleen described something of a gamble that students face when considering drop-in tutoring and open office hours: when there are few students it can be a very helpful resource; however, if there are too many students, it can be a waste of valuable study time. Based on these interviews, it appears that many students do not wish to take that gamble and instead pursue resources that they feel they have more control over.

Learning engagement barriers: Students reported barriers to their engagement in learning using the course-provided materials and the ways in which they use the course materials to complete course tasks. These barriers are shown in Fig. 14 as the top two rows: course resources are misaligned with the complexity of homework tasks, and the homework assessment practices value completion instead of process.

Resources misaligned with complexity of tasks:

Michele: […] there's other people who genuinely didn't know how to do it, and lectures weren't that helpful, recitations weren't that helpful. So when they looked at *the answers [in Chegg] it would tell them the process of how to do it with different numbers, and they would actually learn from looking at that.*

Gil: […] when I saw information the first time I said, "Wow, this is so much more complicated than I thought," because that wasn't anywhere in the lecture to that degree or to that level of complexity.

Online homework values completion over process:

Leigh: […] it's hard because it's an online homework. So no one's giving you partial credit for anything […] so it's really just like the endgame.

Colleen: I think online homework in general is not that great because they more focus on answers rather than the process… it should be more of the process than getting the right answer, but they can't really see your work unless you had to show images of that. So even if you did take time to understand the concepts, the answer is what counts.

Serge: […] for physics, if I submit the wrong answer, that's 3% taken off. You have to make the mistake to learn from it and not make it again… for me, it's because of the stupid flaws I make along the way. It's not because I didn't understand it. And maybe you can say, "Oh, well clearly you didn't understand it if you didn't get right," but it's like I understand the basic concept of it, you know?

Gil: […] you would need to complete it in two tries to get full credit, and the third try would give you less credit. There were, I don't know, countless times, scores of times that I had a question right mathematically and physically, but I was off by three-thousandths of a decimal place and it wouldn't tell me that I had a rounding error. It would tell me that the question was flat-out wrong.

Other barriers included struggles with weekly cycle scheduling, which differed depending on the students' recitation section time, and lack of consistency between course components (lecture, recitation, lab, homework, exams), as Jess noted below:

Jess: So if you have your recitation before lecture, then you have no knowledge in order to pass the quiz [laughter]. And then you have to do these packets during recitation, but if we don't have any prior knowledge from the lecture, then how are we going to pass these packets? I mean, none of the units correlated. None of the variables correlated. PowerPoints didn't correlate with each other. The teacher was not fabulous. It was just overall pretty awful time to spend my Friday.

Rather than viewing undesirable student behaviors as a problem with student preparation, affect, or motivation as is sometimes the perspective taken, it is perhaps more beneficial and productive to embrace the underlying causes of such behaviors: barriers imposed on students by instructors'choices of course structure, resources, and expectations. Students voiced many barriers which influenced their course behaviors, such as their engagement with course- and University-provided resources as well as their engagement in learning. These barriers should be explored within a given University context as such barriers may be context-dependent. In the next Sec. I discuss teaching implications which seek to lower or eliminate the aforementioned barriers in our context in hopes of translation to similar University contexts.

V. DISCUSSION AND TEACHING IMPLICATIONS

In this Sec. I first summarize the extent to which the initial research questions were addressed in this study. I then provide implications for teaching based on results from this study.

Research question 1: What online resources are students using to supplement course-provided materials?

Students from EAP1, AP1, and AP2 primarily used YouTube, Khan Academy, and Chegg in their studying. However, a greater fraction of students from AP1 and AP2 reported using YouTube and Khan Academy, and a disproportionately greater fraction of students reported Chegg use in AP1 and AP2 compared with EAP1. The other reported resources such as Wikipedia, Quizlet, Slader, and various forums were used less by students (with the exception of Quizlet in EAP1), and, while I chose not to focus on those resources in this work, a significant fraction of students reported usage of these resources and so they should not be entirely disregarded.

Research question 2: How frequently are students using these online resources?

Students reported use of YouTube and Khan Academy every week, coinciding with the weekly lecture, recitation, and homework cycle. Interestingly, the vast majority of students who reported any use of YouTube and Khan Academy used them often or occasionally, and comparatively few users did so rarely. For Chegg, reports of any use were lowest in EAP1 and significantly greater in AP1 and AP2, yet for all three course contexts the majority of students who reported any use did so often or occasionally. The high frequency of Chegg use among those who reported its use may be because students pay for the service and would therefore be more likely to use it; however, interviewees also communicated using no-cost third party websites which extract solutions from fee-based sites such as Chegg.

Students who used these resources used them quite often, and these resources represented an integral part of students' approach to studying and tasks in their introductory physics course. Interestingly, when interviewees were asked if they used Chegg in other courses, they reported that they did not use Chegg in chemistry or calculus, whereas YouTube and Khan Academy were used for multiple courses. The interviews also unveiled comparisons of textbook and online resource across students' STEM courses; however, I leave a more detailed exploration of this comparison to future work.

Research question 3: For what purposes and in what ways are students using these online resources?

Students used YouTube and Khan Academy primarily for explanations and clarifications of foundational concepts and problem solving skills, as well as for guided practice. Students used Chegg for access to line-by-line solutions of essentially any textbook or online homework problem assigned, and they typically made use of those solutions in two ways: (i) as a means of copying solutions to mitigate homework credit loss, and (ii) as a form of guided practice via reverse-engineering problem-solving steps and assessing their own problem solving attempt. Chegg usage frequency varied from a staple (or crutch) of every homework assignment to a last resort when all other resources failed to help. Even if students reported little or no use of Chegg, they were aware of how peers used Chegg, which points to the pervasiveness of this tool in students' approach to online homework in our AP1 and AP2 course contexts. Other resources such as general web searches and forums were also used to search for anything from quick clarifications to line-by-line solutions, but to a lesser extent. Interestingly, for the case of Yahoo Answers, some students reported not using it frequently due to the risk of answers being incorrect and untrustworthy. As Serge stated, "*Chegg is by far the best thing to help with [homework]. […] Yahoo Answers would sometimes give you the wrong answer.*" Chegg, originally designed for user-submitted solutions, is also known to have incorrect answers; however, based on the survey results and interview comments, students place more trust in Chegg than other sources such as Yahoo Answers.

Students' use of Chegg generates concerns about authenticity of student work and the extent to which online homework systems reward copying rather than support individual exploration and learning. While online homework systems typically vary the specific numbers used in a given problem, the expected process by which the problem is solved stays roughly the same, and students can simply copy a process but substitute in their numbers. Chegg also offers an expert service by which students pay a monthly subscription ($14.95 USD per month) to get expert feedback within 15 min for any submitted question. While there exist suggestions on how to create novel homework problems or edit homework problems to reduce the ease with which solutions are searched [67], Chegg's expert service undermines any such attempts as students can simply type, copy and paste, screen capture, or take a photo of the question and submit to Chegg and receive a guided solution well within the typical homework time period.

In this investigation it was evident that students sought many resources outside of course-provided materials and activities. When asked why they chose to use resources other than (or in addition to) those provided by the course, students generally spoke of deficiencies in course materials and practices, as well as various barriers to engagement. I focus here on suggestions for improving students' engagement with the textbook, online homework, and in-person resources within our AP1 and AP2 course contexts, that is, large-enrollment introductory physics sequence primarily for a highly diverse population of engineering majors, in the hopes that our experiences translate to similar institutions'contexts. A summary of teaching implication categories and associated suggestions

TABLE II. Teaching implications summary.

A. Supporting textbook use
• Cite specific passages or sections of the textbook in lectures notes and guided examples.
• Incorporate automatically graded reading quizzes into the weekly course cycle.
B. Online homework process: Supporting a learning focus
• Reduce or remove penalties for guesses, or increase the number of tries.
• Choose online homework systems with partial credit, no-penalty hints, process feedback.
• Create a weekly work plan and an activity to familiarize students with the plan.
C. Lowering or eliminating barriers to resources and engagement
• **Time constraints:** Create weekly work plan and activity to familiarize students with it.
• **Schedule conflicts:** Schedule office hours by polling students' availability.
• **Proximity:** Hold virtual office hours and/or review sessions.
• Task **and resource misalignment:** (i) Scaffold homework assignment tasks from low to high complexity. (ii) Use annotated solutions, worked-out examples, and walk throughs of typical problems as activities and resources.
• **Assessments value completion:** (i) Choose online homework systems that allow partial credit, no-penalty hints, and real-time feedback on process. (ii) Employ hybrid format exams: a combination of multiple choice and open-ended questions, or multiple choice questions with space for reasoning or process.

for each category are given in Table II, and are discussed here in detail.

A. Teaching implications: Textbook use

In our context, the textbook chapters and sections are listed in a course syllabus usually as a weekly schedule, but there are no activities or grades associated with students' textbook engagement. Occasionally the online homework may refer to specific textbook pages, figures, or features, but usually as a tangential note rather than a required step for the homework task. If engagement with the textbook is an important course objective, it is crucial that the textbook be better incorporated into course activities, expectations, and grading schemes to motivate its use. I suggest the following:

- **Cite specific passages or sections of the textbook in lecture notes and guided examples** by listing page numbers and a verbal or written cue to explore that resource for more details and information. Providing an exact location of relevant content within a regularly-used in-class resource like lecture notes or slides lowers the barrier for opening any form of textbook and lowers the time commitment to be closer to that of a web search. Be aware that students may use older versions of textbooks to reduce cost, typically the version preceding the most recent version. To account for students' use of older versions of the text, consider noting that the exact location and language of the specific passage may differ between versions, and indicate page numbers for both versions in cases where the language and/or location deviate between the two versions.
- **Incorporate automatically graded reading quizzes into the weekly course cycle using your online homework system or learning management system**. The reading quiz would be separate from the online homework problem set, due just before lecture or recitation, relatively low-stakes, and relatively low complexity and difficulty such that foundational concepts or skills are emphasized. This concept is similar to that of Just-in-Time teaching, a teaching and learning strategy that first has students engage with online foundational materials with an assessment, followed by higher complexity in-class activities informed by the prior online assessment results [68]. A key point is to write a question that addresses a specific textbook passage or figure and cite the textbook page or section in the question statement. Of course students may still choose to do a web search, but this method better incorporates textbook use in a graded activity and lowers the barrier for finding relevant information in the text, making a blind internet search seem a bit more of a hassle than simply opening the book to a predefined page or section.

Alternatively, if course textbook usage is not of high priority but more of a passive resource, then instructors may wish to consider listing a free online textbook as a recommended resource in the syllabus instead of a costly paper book (or associated e-text). There exist free online textbooks via OpenStax for both algebra-based [69] and calculus-based [65] introductory physics sequences which are comparable in content to most introductory physics textbooks, and are being incorporated into online homework systems such as ExpertTA. However, while cost is an important consideration in choosing course materials and activities, it is important that instructors choose materials and activities which best support the learning goals specific to that course.

B. Teaching implications: Online homework process

Online homework assignments are commonly used in large enrollment introductory physics courses primarily for the convenience of instant and automatic grading. This is quite reasonable considering that grading several hundreds to thousands of students' homework by hand each week would be a daunting task even with a large number of teaching assistants, and in such a situation grading consistency is an additional concern that must be addressed. One must consider carefully the goals in having students engage with online homework and whether the homework activities and expectations are aligned with those goals. Additionally, an important consideration is whether the homework activity serves as a formative assessment (relatively low-stakes activity to monitor learning during a unit and provide feedback on strengths, weaknesses, and areas of improvement) or summative assessment (relatively high-stakes activity to evaluate students' learning at the end of a unit); in the suggestions below I assume the homework activity is a formative assessment. Automated online homework systems will likely remain a significant portion of students' activities in our courses, and here I suggest a few considerations to improve students' learning experiences with such systems and encourage students to choose productive exploration over solely seeking credit:

- **Reduce or remove penalties for guesses, or increase the number of tries.** Students regularly reported that the lack of remaining attempts influenced their choice to search for solutions to copy; anxiety of getting their last attempt incorrect and forfeiting credit drove them to copy solutions instead of exploring more deeply. When students were asked if more attempts and more freedom to explore without penalty would reduce their chances of going to Chegg, Michele stated, *"Yes. I'd probably use Chegg less."* Similarly, when Linda was asked if the grading structure is a barrier to how much she can explore, she replied, *"Yeah, getting more attempts. Without penalty."* A study of online homework in physics noted that multiple attempts allow students to explore problem solving approaches with reduced anxiety compared with single-attempt assignments or attempts that severely penalize students' grades [46]. A subsequent study modeled students' problem solving behavior in online physics homework with multiple attempts and suggested five attempts as the optimum number for numerical free-response homework problems [43].

Multiple-choice questions can also be valuable question types to diversify the homework assignment; however, they present unique barriers when it comes to the number of attempts given for a question. Two recent studies in economics suggested using question pools for multiple choice questions whereby subsequent attempts show the student a different version of the question with the same learning objective to mitigate unproductive strategies such as guessing [44,45]. Furthermore, students in an introductory astronomy course treated multiple choice questions with a gamified approach by which they skim text and try to match answers rather than carefully considering the response options, similar to the tactics described in the economics courses [40]. In such situations where multiple-choice questions are preferred by instructors over numerical free-response, or where free-response is not feasible, the authors of the latter study suggested emphasizing mathematically intensive multiple choice problems to mitigate students' use of gamification techniques.

- **Choose online homework systems that allow partial credit, no-penalty hints, and real-time feedback on process (not just correct or incorrect).** Students reported the all-or-nothing nature of online homework system feedback to be unhelpful for troubleshooting where they went astray in their approach. A recent study of online homework attempts in physics suggested that students do not adapt and learn from earlier tries when using a binary feedback homework system [43]; this is consistent with this study's interviews in which students communicated the lack of utility of binary feedback systems in assessing their process. Some online homework systems like ExpertTA and Pearson Mastering Physics have begun including partial credit, real-time feedback specific to a student's approach (distinct from instant feedback of correct or incorrect upon submission attempt), and hints for variable credit loss (the instructor can tune this parameter), which can help transform homework from a binary score based on final answer to a range of scores based on process.
- **Create a weekly work plan to share with students, and an associated activity early in the semester to familiarize them with the plan and the course design intentions.** Such a plan should clearly communicate the ordering and purpose of each activity, as well as how each activity fits in with the other course components. I suggest incorporating a low-stakes graded activity early in the semester to engage students with the course work plan, and following up midsemester (for example, after the first exam) with a low-stakes graded reflection on how their midsemester practices align with the shared best-practices plan, and steps they will take to adjust their approach. The instructor should collect and analyze these responses for patterns (with the help from teaching assistants in large-enrollment courses) and report out to students those existing patterns of behavior and how to adjust for better alignment with the course-specific best practices.

  An early study in physics showed that higher course grades correlated with starting homework early and spreading work out over several days [70]. A more recent study showed that students who spread out their physics coursework across the week have higher exam scores than those who only work on physics content one day per week [71]. Additionally, physics students who copied less than 10% of homework problems worked steadily over the homework period, whereas those who copied more than 30% of the submitted problems exerted little effort early [72]. Importantly, initial ability in physics (as measured by normalized gain in the Mechanics Baseline Test [73]) correlated weakly or not at all with copying behaviors. However, simply telling students of the relationship between homework time management and course achievement has no appreciable impact on students' learning [72], whereas a course plan and associated activity provides opportunities for students to learn about productive course approaches, assess their own approach, and adapt based on instructor guidance [74].

C. Teaching implications: Lowering barriers to resources and engagement

Students reported several barriers to their usage of course- and University-provided in-person resources as well as barriers to productively engaging in their learning in the course. Each barrier given in Fig. 14 is discussed in terms of the cause of the barrier and the impact such a barrier has on students. I first discuss the three commonly reported barriers to using course- and university-provided in-person resources, followed by two reported barriers to learning engagement:

- **Time constraints:** Students' schedules are increasingly packed with course loads and extracurricular activities necessary to be competitive in their fields of study. The typical impact is students focus on time efficiency of their course approach and strategies for maximizing credit in as short a time as possible, especially for nonmajor service courses such as introductory physics for engineers. **Suggestion:** Create a weekly work plan to share with students, and an associated activity early in the semester to familiarize them with the plan and the course design intentions. See online homework process item 3 above for details.

- **Schedule conflicts:** Students have little, if any, spare time between classes to attend in-person resources, and these resources are commonly scheduled during workday hours which coincide with the most popular class times. The general impact is that students are unable to engage with many in-person resources due to class conflicts. **Suggestion:** Rather than scheduling office hours strictly based on instructor availability, schedule office hours in a more informed way by polling students on availability and selecting times that are most popular within reasonable day and time constraints (i.e., many students may be free at 10 pm on a Saturday but that may not be a reasonable day or time). Additionally, asking students' opinions on the in-person resource scheduling shows the instructor values students' engagement with the resource.
- **Proximity:** In large university settings or universities with a high population of commuting students, in-person resource location may require students to commit a significant amount of time just to travel to the resource location. Even for on-campus students, our institution has several separate campuses that require an elaborate bus system to navigate, and if the physics resources are typically located on one campus, yet students live on a different campus, students can spend up to an hour in round-trip travel time just to attend. The impact is students more frequently choose to search online or talk with close-proximity peers instead of engaging with in-person resources led by course instructors. **Suggestion:** Instructors can hold office hours and/or review sessions using common virtual interfaces designed for remote meetings, such as Cisco Webex [75], Zoom [76], Microsoft Skype [77], BigBlueButton [78], etc. Such virtual interfaces only require students to click a link to attend, which makes attending a virtual session competitive with doing an internet search in terms of time commitment. If your institution uses learning management systems, many such systems have built-in virtual meeting applications. Instructors are advised to abide by their institution's standards for virtual communication with students to ensure safe and secure sessions and consider using password-protected sessions to increase security by only publishing the password to students and generating a unique password for each session.
- **Misalignment between task complexity and course resources:** In our large-enrollment course administration teams for AP1 and AP2, faculty leaders rotate every two or three years, generally with little coordination across rotations. A result of this rotation is that online homework assignments are largely recycled from the prior rotation with few if any updates based on students' experiences. Additionally, course leaders are typically research faculty who have little or no training in general pedagogy or discipline-based pedagogy, and pedagogical development is not yet highly valued for tenure considerations in our context. This lack of institutional support for pedagogical development is inevitably detrimental to our students' learning experiences, and one manifestation of this is a misalignment of course task complexity with course resources. Students reported that course resources and materials are simplistic and foundational, yet the homework tasks are highly advanced applications or focus on nuanced details rather than core concepts. The impact of such a gap between task complexity and the level of provided resources is that students seek additional online resources. **Suggestion 1:** Scaffold tasks within a homework from low- to high-complexity cognitive levels. Course activities should be: generated from course goals, scaffolded from low to high complexity to support growth in understanding, and guiding students toward desired course outcomes, i.e., sophisticated problem solving skills, conceptual mastery, and expert-like ways of thinking. Consider evaluating existing homework tasks and editing them such that low complexity foundational knowledge questions appear early in the set, and such questions build up to intermediate conceptual questions or applications, with the most complex or advanced questions being similar to the more difficult exam-like questions. Such scaffolding of activities and alignment with assessments is emphasized by Biggs' constructive alignment [79]. **Suggestion 2:** Incorporate annotated solutions, worked-out examples, and guided walk throughs of typical problems into course activities and resources. A crucial goal in such guided practice and annotated solutions is to model expert-like ways of thinking. A (noncomprehensive) list of annotations in a solution might include: how to set up the problem, finding and applying context clues in the question statement to inform a problem solving approach, generating and assessing consistency between various representations of the situation (a sketch, a diagram, a mathematical formulation, verbal descriptions, etc.) [80], describing why certain steps were taken (e.g., assumptions and their limits), explaining the context-dependent significance of plus and minus signs [81], judging if an answer makes sense based on the context, and more. One may consider creating YouTube videos (public or private) featuring guided problem solving walk-throughs in which specific course objectives are addressed at the appropriate level and using language consistent with course activities and assessments. Benefits of creating YouTube walk-throughs include

promoting student engagement with course-specific materials, reducing the likelihood of relying on unfiltered online resources, and fostering deeper connections with your students [22].

- **Assessments value completion of tasks:** Online homeworks and multiple choice exams are typically binary tasks which only assess completion and have no measure of process. In binary homeworks, students are incentivized to get correct answers by any process, including time-efficient methods of copying solutions which circumvent (or at least postpone) the learning process. In binary multiple choice exams, students tend to focus on problem solving heuristics and test-taking strategies rather than expert-like approaches [82]. **Suggestion:** For online homeworks, see the second suggestion of Online Homework Process above. For exams, consider the following: (a) Open-ended questions tend to elucidate students' approaches such that the grader can better establish how the student arrived at an answer. Incorporating one or two open-ended questions on core concepts for an exam, combined with more easily graded multiple choice questions, better balances the assessment to value process in addition to correctness. (b) In large enrollment courses where open-ended questions are logistically difficult, consider adding a reasoning or process section under each multiple choice question as a means of evaluating (by hand) partial credit for students who choose an incorrect answer. This concept is similar to hybrid format tests in the field of psychology [83]. While it is possible students arrive at correct answers with inconsistent reasoning, focusing only on incorrect answers reduces the logistical struggle of this method and enables deeper feedback opportunities by recognizing productive aspects of the student's approach.

D. Limitations

It is possible that some participants did not respond honestly in the survey or the interview due to the perceived risk of academic integrity violations in their dishonest use of resources, despite being informed that their individual responses would not be shared with the course leaders. This idea is supported by a prior study which showed that detected instances of copying were greater than the self-reported copying by students in an anonymous survey [72]. As such, I suspect the survey data underestimate the number of students who use Chegg as well as its frequency of use, given Chegg being branded as a mechanism for cheating in this study's course contexts. To minimize these tendencies in the interview, I reminded participants that I (the interviewer) was in no way affiliated with the course grading or practices, and that the students' individual data would remain anonymous.

The interview population consisted of 11 randomly selected students out of a larger pool of 319 volunteers, and the volunteer pool represented just 48% of the 669 survey respondents and 21% of the 1527 total enrollment. This self-selection process limits the generalization of these results to the entire population of each course because some student groups may be less willing to participate than others. Additionally, the interview population was constrained to students from AP1 and AP2 which limited the scope of this study in that I focus on deficiencies in the AP1 and AP2 courses; that is, I do not explore the potential impact of the strengths and surplus of course resources in the EAP1 course on students' resource use. Furthermore, students' perceptions and use of resources presented here result from their experiences in our courses, and while the course contexts and course components discussed in this study may be similar to other large research-intensive universities, instructors should be mindful of differences in their course contexts compared to that of this study when considering the teaching implications and suggestions.

The study participants represented around 50%–60% of the course populations (excluding the anomalous case of AP2), yet roughly half of the students in each course did not attempt the survey or completed the survey but did not agree to include their data in the study. Future survey implementations will be more consistently advertised across the courses, and I will explore additional means of motivating student participation to capture more student perspectives.

VI. CONCLUSIONS AND FUTURE WORK

Free online resources for education continue to expand and become accessible to a wider audience, and this has had an impact on the ways in which students engage with introductory physics courses in the context of this study. Students reported infrequent use of the textbook yet frequent use of online resources in this context. While part of this is due to the lack of course activities and structures necessitating the textbook, another aspect is the reported gap in complexity between highly complex homework tasks and the low complexity guided practice and explanations in the textbook and lecture notes. To bridge this gap, students sought resources that more directly addressed their specific struggles when studying or doing homework, such as walk-through videos, line-by-line solutions, or close-proximity peers.

Students reported time as a limiting factor in the kinds of resources they chose: in-person resources provided by the course or University require round-trip travel times of up to an hour for resident students, not including the interaction time. Additionally, online resources sufficed to answer many of their questions in a matter of seconds to minutes via a web search. Students also reported time as a factor influencing the way in which they use the resource: to productively explore a struggle when much time remains, or to unproductively copy solutions to mitigate loss of assignment points when little time remains.

Chegg presents a unique challenge to course administrators in its easily available solutions to essentially all textbook problems and quick turnaround for solutions of user-submitted course materials. Chegg typically is thought of by course leaders as a source for cheating on homework and other course tasks; however, it is evident from this study that many students were aware of the detrimental impact of copying solutions on their learning and success, and fully recognized that if they used Chegg to cheat they would need to revisit their learning struggles later in preparation for the exam. Additionally, students reported using Chegg as a source of guided practice, such as to clarify steps taken in a solution and to help elucidate why the steps were taken. While some fraction of students will seek resources for dishonest purposes, this study elucidates the perspectives of students who genuinely want to learn and are seeking resources to support their efforts.

Future work will focus on exploring correlations between students' modes of resource use and their scores in homework, exams, and final course grades. Additionally, I will further explore barriers to in-person resources and ways in which instructors can provide more accessible versions of such resources. Furthermore, I plan to change course expectations and policies, such as the homework grading policy and providing more guided practice examples and tasks, to determine if, and how, such changes impact students' engagement in the course and their use of online resources.

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APPENDIX A: ONLINE SURVEY

I present the online survey to which students responded in this study. These questions were given as part of a larger set of questions not presented here.

1. Choose the following that best describes your usage of the course textbook this semester (select all that apply)
   - Textbook readings were freely provided by the course
   - Purchased NEW paper textbook
   - Purchased USED paper textbook
   - Purchased electronic (online) textbook
   - Rented textbook
   - Borrowed someone else's copy of textbook
   - Used a library copy of textbook
   - Did not obtain any paper or electronic copy of textbook
   - Used OpenStax University Physics free online textbook
   - Other (please describe usage in the textbox)
2. How important is textbook cost in your choice of textbook usage from the question above? (select one)
   - Very important
   - Somewhat important
   - Not important
3. How often did you use the course textbook in your studying this semester? (select one)
   - Often (1–2 times per week or more)
   - Occasionally (1–2 times per month)
   - Rarely (1–2 times per semester)
   - Never
4. Describe how frequently you used the resources listed below in your studies for this course (for each resource, select one of the following: often, occasionally, rarely, or never):
   - Wikipedia
   - YouTube
   - Khan Academy
   - Chegg
   - Slader
   - Quizlet
   - Other (please write in other resources used and indicate frequency of use)
5. In general, how frequently do you use any online resources in your studies for this course?
   - Often (1–2 times per week or more)
   - Occasionally (1–2 times per month)
   - Rarely (1–2 times per semester)
   - Never

APPENDIX B: INTERVIEW PROTOCOL

I present here the interview protocol used for student interviews. In these semistructured interviews, follow-up questions stemming from the protocol questions are frequently asked which result in slightly different interviews for each student.

1. Part 1: Student background and general questions

1. Please state your name, your major, and your academic year at Rutgers (1st year, 2nd year, etc.).
2. Tell me about why you decided to attend college.
3. Tell me about why you chose your major.
4. Please describe why you are taking this physics course, and why you chose Analytical Physics rather than other equivalent courses, such as Extended Analytical Physics.
5. Describe your level of experience and interest in physics before taking this course compared to after having taken the course.

6. What aspect of the course (lecture, workshops or recitation, online homework) was most helpful in your learning this semester?
7. What aspect of the course (lecture, workshops or recitation, online homework) was least helpful in your learning this semester?
8. What was your favorite part of the course?
9. How often do you attend lecture? What do you think is the purpose of the lectures in this course?
10. How often do you attend workshop or recitation? What do you think is the purpose of the workshops or recitations in this course?
11. How often did you complete the homeworks? What do you think is the purpose of homework in this course? For other courses?
12. Was there any weekly structure to the course? How did the lectures, workshops, and homeworks relate to one-another, if at all?

2. Part 2: Online survey follow-up questions

13. Please review this printout of your survey responses and confirm that they are in fact the responses you provided.
14. Based on your survey, you reported using (insert participants response: online textbook OR traditional textbook OR both). Please describe how you used the textbook this semester, and how often you used it.
    - Is there anything about the textbook or the way its used in the course that contributes to your usage frequency? If so, explain.
    - How does your textbook usage compare to how you use the textbooks in other courses?
    - In general, do you find textbooks to be a helpful resource? If so, in what contexts and for what purposes? If not, why not?
    - If only one textbook was used (online textbook or traditional textbook), what factors influenced your choice to use that textbook over the other textbook?
    - If both the online textbook and traditional textbooks were used, how do they compare? Did you use one more than the other? Why?
15. Based on your survey, you reported using the following online resources (insert participants survey responses) with a frequency of (insert participants reported usage frequency).
    - Please describe how you found out about these resources, or how did you first start using these resources?
    - Have you used these resources for other courses? If so, which resources, which courses, and why or how use them for the other course? If no, why have you used these resources only for this course?
    - For each resource you listed, please comment on how frequently you used that resource, and for what purpose it was used.
    - Are there any other online resources you used during the course that weren't discussed so far?
16. Besides what was already discussed, what other resources did you use outside of the graded course activities to help in your studying? For example, office hours, Learning Assistant study groups, tutoring, the Learning Centers, informal meetups with your peers, etc.?
17. If the student has used resources for finding homework solutions or exam solutions, or is aware of peers who do:
    - What are your general thoughts on online resources that have textbook solutions, such as Chegg or Slader?
    - For what purposes do you think your classmates might use these resources?
    - If you or your classmates have used these kinds of resources to find solutions, how do you use the solutions once you've found them?
    - Do you think more people use these resources to help understand their own struggles with a given problem, to find a verbatim solution to get a correct answer on the homework, or for other reasons?
    - Describe your thought process when working through a particularly difficult homework problem or practice exam problem. Specifically, how do you decide what resources to use when you encounter a point of struggle?
    - Does the way you approach your online homework depend on how much time you give yourself to complete it? For example, do you approach it differently if you start earlier compared to completing it the night before its due?

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