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Adaptive Learning Courseware as a Tool to Build Foundational Content Mastery: Evidence from Principles of Microeconomics

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ADAPTIVE LEARNING COURSEWARE AS A TOOL TO BUILD FOUNDATIONAL CONTENT MASTERY: EVIDENCE FROM PRINCIPLES OF MICROECONOMICS

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INTRODUCTION

Across higher education, there has been a call to find "ways to decrease costs while delivering high quality education to an expanded and more diverse student body… (APLU, 2016a)." This recognition of the importance of teaching, while at the same time acknowledging that teachers are expensive, demands that higher education embrace new models for learning. One model for learning that appears to promise improvements within this "iron triangle" of quality, cost, and access is adaptive learning. Adaptive learning is an approach for personalized learning which moves learning away from a "one-size fits all" to meeting the needs of each learner (Tyton Partners, 2013). Adaptive learning courseware is recognized as having the potential to make a difference in student outcomes by making personalized learning scalable.

Adaptive learning courseware is technology that requires students to master the same learning objectives, but the order and timing of content is determined by the adaptive software engine that assesses the student's performance on a number of factors and then guides the student through the course content. Adaptive courseware has been available for more than a decade (e.g., ALEKS for mathematics) but recently is expanding to other disciplines (e.g., economics, foreign languages, business, anatomy and physiology) and is used across all levels of education including K-12 (McCarthy, Schauer, & Joint 2017), higher education, and professional development (Sharma & Szostak, 2018).

The sophistication required for the adaptive software has resulted in this courseware most often being available from educational technology vendors and/or publishers. There are two general types of adaptive courseware: (1) courseware where an instructor can author content within a provided adaptive delivery method (i.e., instructor-authored content), and (2) courseware from publishers or other vendors who provide the content as well as the adaptive delivery method, often affiliated with a particular textbook (i.e., publisher-authored content). Examples of platform providers that allow instructor-authored content include Cerego, CogBooks, Knewton, LoudCloud, Realizeit and Smart Sparrow, among others. Publishers reinventing themselves as educational technology companies, with adaptive learning often taking the lead, include Cengage (Difference Engine by Learning Objects), McGraw-Hill Education

(LearnSmart, ALEKS), Pearson (MyLab and Mastering), and John Wiley & Sons (WileyPLUS with ORION), among others. Within these courseware, there is significant variability of how much content can be customized, algorithm, and depth of coverage. For example, LearnSmart does not allow any instructor-authored content but does allow some customization through the selection of learning topics and average length of assignment. Realizit, as a comparison, enables a much higher level of customization by allowing instructor-authored content. The adaptive algorithms also vary between courseware, many of which are proprietary and therefore unobservable. Depth of coverage can also vary across courseware where some courseware emphasize foundational learning objectives at the bottom of Bloom's taxonomy and other courseware involve higher levels of Bloom's more frequently. Bloom's taxonomy is used to classify educational learning objectives, where at a lower-level on the taxonomy, students define, identify, or explain concepts and at a higher-level, students calculate, implement, or solve problems (Anderson & Krathwohl, 2001). Regardless of overall depth of coverage, as the student progresses through the assignment, the courseware will vary depth of coverage among levels of the taxonomy.

Adaptive learning courseware is a technology that is seen as having the potential to improve educational outcomes. A recent poll of college and university presidents shows that a majority of the survey's respondents (66%) see potential in adaptive learning to make a "positive impact on higher education" (Lederman, 2013). Additionally, major organizations have backed research related to adaptive courseware. For example, the Bill & Melinda Gates Foundation initiated in 2013 the Adaptive Learning Market Acceleration Program (ALMAP) to advance evidence-based understanding of how adaptive learning technologies could improve opportunities for low-income adults to learn and to complete postsecondary credentials (SRI Education, 2016). The Association of Public and Land-Grant Universities (APLU) founded the Personalized Learning Consortium, also in 2013, to facilitate public universities to exchange information about personalized learning technologies, such as adaptive learning courseware, that will improve student success (APLU, 2016b). Additionally, adaptive learning has been highlighted in popular media outlets such as Slate (Oremus, 2015), Forbes (Ingham, 2015), and the New York Times (NYT, 2016; Gabriel & Richtel, 2011) as well as not-for-profit educational organizations, such as EDUCAUSE, as a "Top 10" Strategic Technology for 2016 (Grajek, 2016).

Despite the enthusiasm for the technology, relatively few studies have been conducted to determine the impact of the adoption and use of adaptive courseware on student outcomes with varying results. The broad ALMAP study included 14 higher education institutions and 23 courses ranging from 15 gateway general education courses (economics included) and 7 developmental education

courses. Results from this study were mixed and indicate that some courses using adaptive courseware resulted in slightly higher course grades but the majority had no discernible impact on overall course grades, the odds of successfully completing a course were not affected using adaptive courseware, but in seven controlled side-by-side comparisons of scores on common learning assessments (i.e., exams), the average impact of was modest but significantly positive (SRI Education, 2016). Some studies show that adaptive courseware show no impact on outcomes. For example, Murray and Pérez (2015) in a study related to a digital literacy course found that student learning, measured by two examinations, did not vary significantly across the sections when comparing an adaptive learning versus a more traditional quiz method as a mode of instructional delivery and assessment. Griff and Matter (2013) found no significant improvement on posttests relative to pretests, grade distributions and retention between sections using only adaptive learning courseware or online quizzes of equal length in time to complete in an undergraduate anatomy and physiology courses at six schools. Other studies show a positive impact. Results from a study evaluating the effectiveness of ALEKS (an adaptive learning courseware) in college algebra courses showed that the students using the courseware outperformed students not using the courseware on a comprehensive final exam (Hagerty & Smith, 2005). McGraw-Hill Higher Education (MHHE) conducted independent effectiveness studies for their adaptive learning courseware (LearnSmart) and results from seven studies related to various courses and a study of nearly 700 students studying anatomy and physiology at six distinct institutions indicated that the use of adaptive courseware improved exam scores, course grades, and retention (MHHE, 2015).

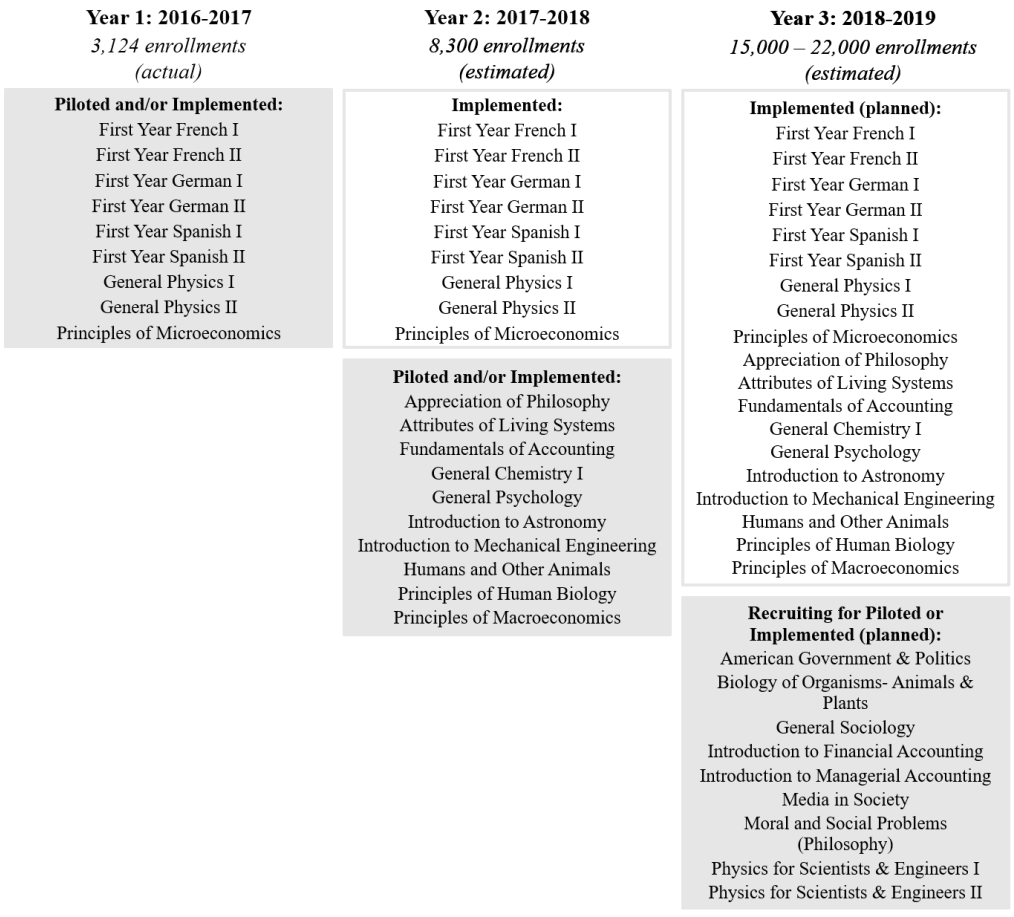
Adaptive learning courseware tends to be self-paced, is often graded based on completion, allows for flexibility in the timing of completion, and frequently includes features to improve metacognitive awareness. This courseware is a different way for students to interact with course material. Research that simply compares grade outcomes between courses that use quizzes versus courses that use adaptive learning do not provide a deep understanding of the strengths and limitations of the adaptive courseware. Because of the unique characteristics of adaptive courseware, using this tool can lead to higher levels of content mastery by allowing the student to take a variety of paths, focusing student effort towards content not mastered, and requiring the student to keep working, often within more foundational learning objectives, until mastery is demonstrated. This research explores the idea that rather than replacing alternative forms of assessment, adaptive courseware is better thought of as a tool to build a specific content mastery that results from the unique characteristics of the specific courseware, which must be combined with other forms of assessment and remediation.

ADAPTIVE LEARNING COURSEWARE AT COLORADO STATE UNIVERSITY

To explore how adaptive courseware can potentially address the iron triangle of quality, cost, and access, in July 2016, the APLU through the Personalized Learning Consortium awarded eight universities grants funded by the Bill & Melinda Gates Foundation to accelerate the implementation of adaptive courseware in high-enrollment and blended learning environments to improve student success. These universities [Arizona State University, Colorado State University (CSU), Georgia State University, Northern Arizona University, Oregon State University, Portland State University, University of Louisville, and University of Mississippi] were each awarded approximately $500,000 over three years to "adopt, implement, and scale use of adaptive courseware (APLU, 2016b)."

At CSU, the APLU grant was used to integrate adaptive courseware in up to 28 courses staggering the implementation across three years (Figure 1). These courses span many departments (e.g., Chemistry; Economics; Languages, Literatures, & Cultures; Life Sciences; Mathematics; Physics; and Psychology). Most of these courses are high-enrollment and many have high rates of students earning a D or F grade or withdrawing from the course. Principles of Microeconomics was part of the first-year cohort.

Figure 1: Adaptive Courseware Implementation Progress, Colorado State University



To promote student success at CSU, the courses involved with the APLU grant integrated adaptive courseware and high-impact educational practices in mutually reinforcing ways. By doing so, CSU supports a larger vison of general education that will link robust learning to integrative learning and will guide students in developing productive strategies for self-regulated learning (CSU, 2016). In general, CSU's belief is that successful integration of any learning assessment, tool, or activity must make sense in the overall course design. Research supports the use of adaptive learning courseware for formative assessment (Spector, et al., 2016) and best practices recommend that adaptive content must be aligned with course learning objectives (Wozniak, et al., 2016).

Adaptive courseware assignments were implemented in every resident (i.e, on-campus or face-to-face) instruction section of Principles of Microeconomics at CSU fall 2016 excluding the honors section (5 sections total). Principles of Microeconomics is a freshman or sophomore level course that introduces students to how economists model the decisions made by households, firms, and government, and how these agents interact in a market setting. This course is high-enrollment and is considered foundational as part of the university core curriculum and gateway as a required class in over 40 majors. Each section of this 3-credit course was structured in a lecture-recitation format taught by four instructors assisted by a total of 12 graduate teaching assistants. Students attended a large 180- or 270-student lecture twice weekly led by the instructor and a small 30-student recitation once weekly led by the graduate teaching assistant. The sections were coordinated and followed the same schedule (e.g., each section covered the same content in lecture and recitations, students completed the same quizzes and adaptive learning assignments, exam questions were drawn from a pool of questions developed by the instructors). To support student success, the instructors and graduate teaching assistants followed text closely in lecture and recitation. This is a deliberate design because the adaptive courseware is based on the learning objectives and language in the text. Assessments in this course included iClicker points for nearly every class session, almost weekly low-stakes adaptive learning assignments and higher-stakes quizzes, two high-stakes writing assignments, and three exams. The adaptive assignments were assigned 13 out of 15 weeks and were very low-stakes (13 points out of a possible 500 or approximately 2.6% of final grade). The instructor-selected average time required for the weekly adaptive assignment was 15-20 minutes and sections of the chapter covered in lecture and recitation were included in the assignment. Quizzes were higher stakes, each worth 10-points per assignment, and included more difficult higher-level Bloom's questions which often closely reflected recitation activities.

The adaptive courseware used in Principles of Microeconomics was LearnSmart by McGraw-Hill Education, which has publisher-authored content. This courseware was selected because it was associated with the course textbook. LearnSmart assesses the student's skill, knowledge as well as their confidence level around that knowledge and uses these variables to adapt his or her progression through the learning content to ensure mastery (MHHE, 2015). This adaptive courseware continually reassesses the student's progress to identify knowledge gaps, adjust objectives, and map out a student-focused instructional path (Tyton, 2016).

Progressing through LearnSmart, students answer a series of questions and indicate their confidence level (to build metacognition). The types of questions, or "probes," associated with each learning objective are typically multiple choice, but true/false, multiple answer, or matching questions, among others, are also used. Although this courseware does not allow any instructor-authored content, there may be 100-200 publisher-authored questions per chapter. Multiple types of remediation are available, including a virtual mentor, linked access to the relevant sections in the eBook (the "SmartBook"), instructional videos, correct/incorrect indicators, explanations, and other types of learning objects. Students can freely access the remediation throughout the assignment, supporting reading of the textbook and additional moments of learning. Students can complete the assignment all at once or complete in multiple logins, with the system maintaining and returning them to their current position in the content. If a student answers questions correctly with confidence, he or she will progress more quickly than a student who answers questions incorrectly or without confidence. Since the assignment is based on completion, all students must demonstrate mastery, as shown by receiving full credit on the assignment, of the learning objectives associated with the assigned sections of the chapter. These characteristics of the adaptive courseware, along with CSU's holistic perspective on course design where adaptive is important but not the only tool, informed how the courseware was integrated into Principles of Microeconomics.

For each LearnSmart assignment, the instructor selects publisher-identified sections of the chapter and identifies average time required (so-called "depth of coverage"). The longer the average time, the more learning objectives are covered. The courseware focuses on foundational learning objectives at the bottom of Bloom's taxonomy. Some of the learning objectives involve higher levels of Bloom's, but these are relatively few in number. If an instructor selects a shorter average time for assignment completion, then fewer of these higher-level Bloom's will be presented to students. Therefore, based on this structure limitation, it is important to view this adaptive courseware as a tool to build lower level Bloom competencies.

METHODS

The unique characteristics of LearnSmart adaptive courseware as detailed in the previous section, in particular the key characteristic of focusing on lower-level Bloom's, guided this study design. This study explores the relationship between student interaction with the adaptive learning courseware and content mastery by comparing completion of adaptive learning assignments and success on parallel questions on exams.

In all five sections, 962 students were enrolled at the end of the semester, of which 932 completed the final exam. For this study, a sample population was identified. The entire population of students was not included due to incomplete data across all 5 sections and limited resources to gather and organize data. Students included were in sections of the course taught by the author (which included a total of 442 of students or 43.7% of all students) and every fourth student based on the alphabetical ordering last name in each section was selected as part of the sample population (n = 109). In this student population, there were 54 freshmen, 34 sophomores, 16 juniors, 4 seniors, and 1 graduate student. Thirty-three majors were represented, and the most prevalent major was Business Administration and Undeclared Students Seeking the Business Administration major (n = 41). Three economics majors were in the sample.

To determine if use of the adaptive courseware improved content mastery, students completing and not completing the adaptive assignment on a weekly basis, typically corresponding to a chapter's worth of material, were identified and then the correctness of parallel questions on exams were compared. A student is considered a "completer" if any time is spent on the adaptive assignment by the due date either by attempting some or completing all the assignment. A "noncompleter" is a student who spent no time on the adaptive assignment by the due date. To identify the parallel questions in the exam pools, each chapter's questions were coded into 3 levels according to difficulty (1 = easy, 2 = moderate, 3 = difficult) based on the publisher's difficulty rating and instructors' perception of difficulty using Bloom's taxonomy as a guide. "Easy" corresponds to the lowest level of the taxonomy (i.e., knowledge) and uses keywords such as define, identify, and choose. "Moderate" corresponds to a higher level on the taxonomy (i.e., comprehension) and uses keywords such as explain, interpret, and show. "Difficult" corresponds to an even higher level on the taxonomy (i.e., application) and uses keywords such as calculate, implement, or solve. If a student attempted some or completed all of a week's adaptive assignment, their average score on the 'easy' exam questions associated with that week were included in the 'completers' data. If a student did not complete a week's adaptive assignment, their average score on the 'easy' exam questions associated with that week were included in the 'noncompleters' data. These average scores of completers and

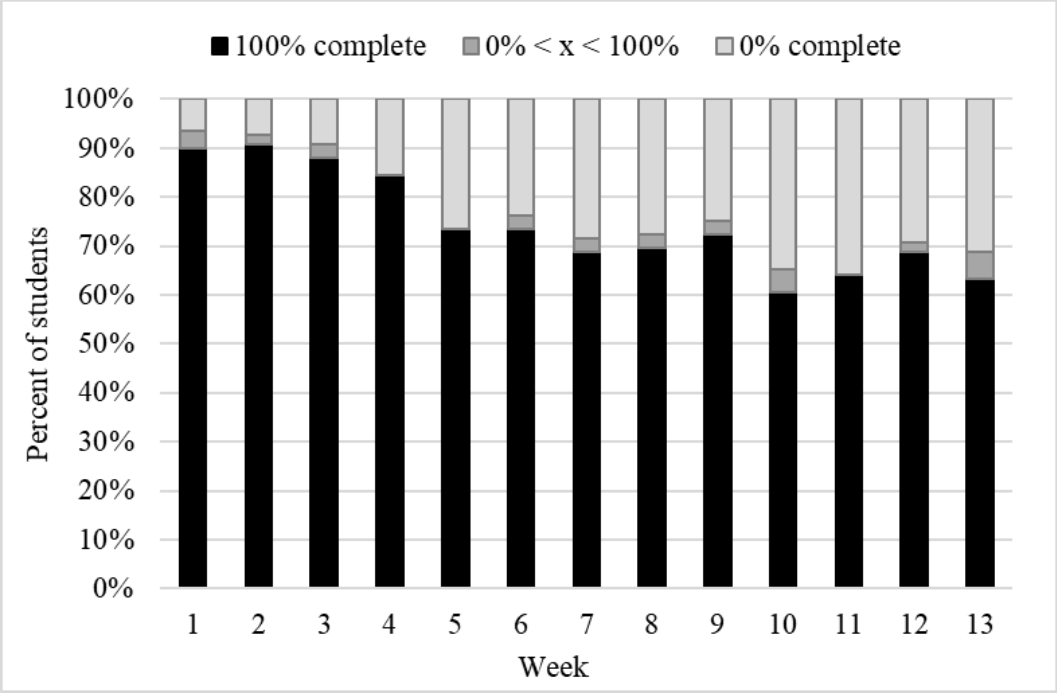
noncompleters by week were then aggregated for all weeks. It is hypothesized that completers will show a higher level of content mastery as compared to noncompleters on the "easy" exam questions as measured by more questions answered correctly. For example, the students attempting some or completing all the LearnSmart assignment associated with week 3 will answer the week 3 "easy" exam questions with more accuracy.

RESULTS

A total of 295 minutes of adaptive learning assignments were assigned but students spent much less time on average to complete the assignment (156 minutes). Although some students spent a lot of time on the assignments, on average, students did not spend more than 14 minutes per assignment and several students' averages were 7 minutes (weeks 10 and 13).

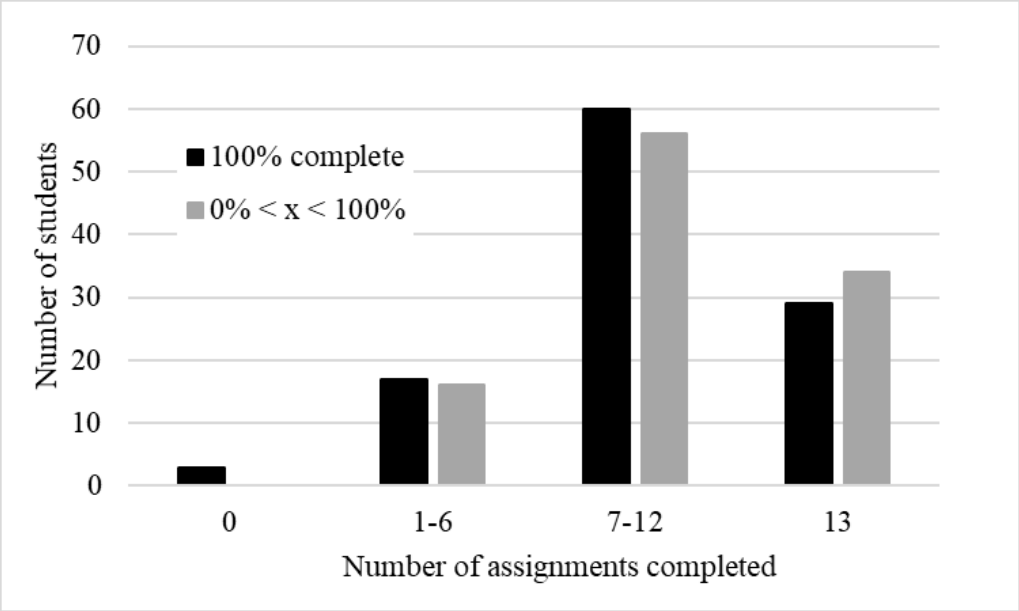
Most weeks students were "completers" and attempted some (0% < x < 100% completion) or completed all (100% complete) of the adaptive learning assignment each week as summarized in Figure 1. For example, in week 1 89.9% of students completed all of the assignment, 3.7% attempted some, and 6.4% were noncompleters. In week 5 73.4% of students completed all of the assignment, 0% attempted some, and 26.6% were noncompleters. More students completed the assignment earlier in the semester as compared to later in the semester. An average of 88.3% of the students completed the first four assignments which dropped to 64.2% on the last four assignments.

Figure 2: Adaptive learning courseware assignment completion by week



As summarized in Figure 2, about one third of students attempted all adaptive learning assignments by the due date (34/109), and more than 86% of students attempted or completed at least half of the assignments (94/109). Only 3 students did not complete any assignment.

Figure 3: Adaptive learning courseware assignment completion



Do these completers score better on parallel exam questions? The null hypothesis, H0, may be stated as: "The mean of correctness for 'easy' questions for the noncompleter group is equal to that of the completer group." An independent-samples t-test was conducted for performance on "easy" questions for completers and noncompleters. The t-test assesses whether the means of two groups are statistically different from each other. There was a significant difference in the scores for completers (M = 83.3, SD = 28.3) and noncompleters (M = 74.8, SD = 33.7) conditions; t (455) = 4.1, p = 0.00005. The results indicate that H0 must be rejected using the standard α = 0.05 level of significance. Students completing the adaptive assignment outperformed the noncompleters. The mean correctness for completers is 83.3% and for noncompleters it is 74.8%. The completers, on average, answered 23.32 (out of 28) questions correctly whereas the noncompleters answered 20.94 correctly. These results suggest that completing the LearnSmart adaptive learning assignment has a positive, significant effect on performance for corresponding easy questions on the exam.

An additional independent samples t-test to compare student performance on moderate questions for completers and noncompleters was conducted. There was a significant difference in the scores for completers (M = 79.1, SD = 30.5) and noncompleters (M = 72.1, SD = 34.1) conditions; t (424) = 3.12, p = 0.001. The results are similar in that the null hypothesis that the means are the same between the completers and the noncompleters on the moderate questions must be rejected. The completers, on average, answered 19.77 (out of 25) questions correctly whereas the noncompleters answered 18.02 correctly. The difference in the means is larger for the easy questions (8.5%) as compared to the moderate questions (7%). This is consistent with what was expected because the adaptive learning courseware emphasizes the foundational course content found on the lower levels of Bloom's taxonomy and other assignments such as recitation activities and weekly quizzes emphasized higher level Bloom's.

Completers, on average, earn higher grades on the easy and medium questions on exams which, when generalized, have a positive impact on course grades. For example, focusing only on the difference in success between complete and noncompleters on easy questions, the completers answered more questions correctly, a completer would have on average a 1.43% higher end-of-semester grade. When combining this result with the difference in success for the moderate questions, students who attempt or complete all the adaptive learning assignments would have a semester grade on average that is 2.48% higher than noncompleters. When analyzing actual end-of-term course grades, students who completed all of the adaptive assignments averaged 3.05 (on a 4.00 scale). For students who attempted or completed at least half but not all, (50% > x < 100%) the average end-of-term grade was 2.72 (on a 4.00 scale), an insignificant difference at the α = 0.05 level. This result suggests that the most studious students who complete all of the adaptive courseware assignments may not be the "best" students in class. Instead, it may be that these students are the ones who recognize they need the practice and the course credit.

DISCUSSION

Improving student outcomes is a goal for higher education faculty and administration and adaptive learning courseware has the potential to enhance quality, decrease cost, and improve access in higher education. Results from this study indicate that students who completed the low-stakes adaptive assignment outperformed their peers who did not complete the adaptive assignment on easy and moderate questions on the exam that could result in a higher course grade. This suggests that if adaptive learning courseware is integrated as low-stakes assignments then student outcomes can be improved with relatively little effort on both the side of the instructor and the students.

One challenge is to encourage instructors to integrate adaptive courseware assignments into the curriculum. For the courseware with instructor-authored content, the significant time required to author questions can deter faculty from using this type of courseware. Departments and administration can support this effort through helping faculty members collaborate to author questions. If faculty have no time or interest in authoring questions, they can look towards publisher-authored content. Adaptive courseware is likely included when students purchase eBooks through large publishers for high enrollment or gateway courses. Faculty should be encouraged to integrate this courseware, especially since there is often no extra cost for student access.

Further study is needed to more broadly determine the impacts on student success related to the adoption of adaptive courseware. These data from this study could be combined with institutional data to better understand if completion of the adaptive assignments disproportionally benefited first generation, nontraditional, or minority students, or helped to close the gap between students who had high and low levels of college preparedness. Additionally, these data could be combined with data from other course assignments and student attendance data to create a more wholistic picture of the role of adaptive courseware in promoting and supporting student success. Finally, when observing the rate of completion of the adaptive assignments, some students completed all of the adaptive assignments (26.6%) and many students completed most of them (67% of students completed >70% of the assignment). It could be the case that a particular student could be a completer one week and a noncompleter the next. This research does not analyze the success of a particular student when they complete or not. Instead, this looks at overall patterns of behavior and how that is related to success. Further research as well as additional statistical analysis is necessary to identify the impact of completion on individual student outcomes.

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