THE OPEN LEARNING INITIATIVE (OLI) ONLINE STATISTICS COURSE: HOW STATISTICS EDUCATION HELPED DEFINE PROMISING DIRECTIONS FOR THE USE OF TECHNOLOGY-ENABLED INSTRUCTIONS IN HIGHER EDUCATION

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As part of the Open Learning Initiative (OLI) project, Carnegie Mellon University was funded to develop an online introductory statistics course designed to effectively support learners without an instructor. The OLI Statistics course is perhaps the most systematically studied of all online university courses and has been shown to be effective in a variety of higher education settings both in the online-only and hybrid instructional models. This paper discusses how the OLI Statistics course and its design features support both students and teachers, presents the course assessment results, and describes how these results have placed statistics education at the forefront of the discourse on how technology-enabled instruction can be used to improve learning outcomes while taking on the so called, "Cost Disease" in higher education.

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INTRODUCTION

In the mid 1960s the two economists Baumol and Bowen described the "Cost Disease" in sectors that relay heavily on human interaction such as education, where there are fewer opportunities for technological advances that lead to increase in labor productivity (Baumol and Bowen, 1966). In the context of higher education, the cost disease refers to the push to higher salaries (and hence cost in general) in response to rising salaries in goods producing sectors (such as car manufacturing) that have been able to significantly increase labor productivity through technological innovations and thus keep cost increases within the rate of inflation. Baumol and Bowen's theory seem to present higher education with a dilemma. On the one hand, increasing productivity by reducing the cost of instruction per student (i.e., large lecture classes) will lower the quality of education provided. On the other hand, if we do not increase productivity, the Baumol/Bowen cost disease guarantees that more and more people will be priced out of quality education (Thille & Smith, 2012). Carnegie Mellon's Open Learning Initiative (OLI), an open educational resources project that began in 2002 with a grant from the William and Flora Hewlett Foundation, had hoped to challenge Baumol and Bowen's dilemma by providing access to high quality education while at the same time increase productivity.

As part of OLI project, Carnegie Mellon University was funded to develop an online introductory statistics course. The goal of the funder was to provide open access to high-quality post-secondary educational materials to individual learners who otherwise would be excluded or not encouraged to pursue higher education (Smith and Thille, 2004). The course was developed by a team of statistics faculty members who specialize in statistics education, learning scientists, human-computer interaction experts, and software engineers in order to make best use of multidisciplinary knowledge for designing effective instruction.

THE COURSE DESIGN

The OLI Statistics course was designed with an explicit focus on incorporating learning science principles (e.g., Ambrose et al., 2010). It is well established that applying learning science to the design of technology-enhanced learning consistently leads to improved learning outcomes (GLC, 2016). One such principle is the importance of "connected" rather than "fragmented" knowledge. Learning scientists agree that how students organize knowledge determines how they retrieve it and apply it. The course is designed to help students make connections that form knowledge structures that are accurately and meaningfully organized. The course starts by presenting to students a "Big Picture" view of Statistics – i.e., how the different units in the course fit together conceptually – and then refers back to this at key transition points throughout the course (Lovett and Meyer, 2014). Figure 1 shows this "Big Picture" as students see it when starting the exploratory data analysis part of the course. A clear structure and organization is maintained within each course unit and module, emphasizing how the different skills that the students are learning fit together in a meaningful way.

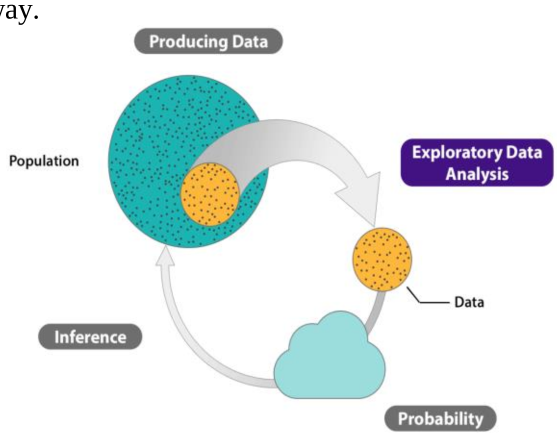

Figure 1. The “Big Picture” as highlighted by the OLI Statistics course

To incorporate the principle that goal-directed practice with targeted feedback enhances the quality of students’ learning, interspersed with the textual explanations of concepts and worked examples, are interactive tasks that support students to engage in practice with the concepts and skills that they are learning. For example, throughout the course, “Did I Get This” activities prompt students to check their comprehension and provide immediate feedback that reinforces correct responses and targets common misconceptions. Studies have shown that immediate feedback leads to significant reduction in time taken by students to achieve a desired level of performance (Anderson et al., 1989), and according to Grant Wiggins (1997), former president of the Center of Educational Assessment, “It’s not teaching that causes learning. Attempts by the learner to perform cause learning, dependent upon the quality of feedback and opportunities to use it.” Figure 2 shows a “Did I Get This” activity in the course related to probability’s addition rule and the tailored feedback that the system provides when the student answers this question incorrectly.

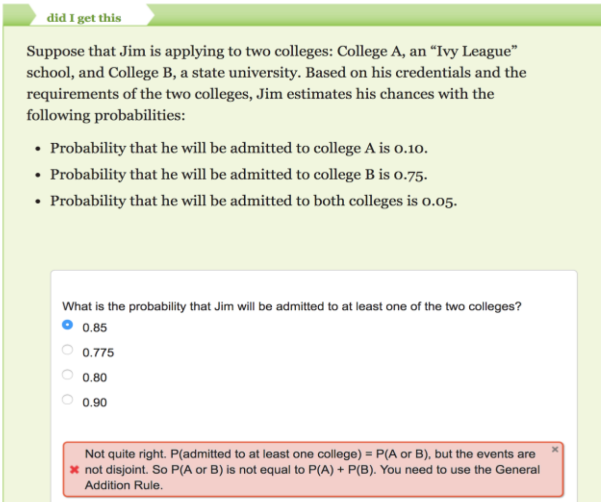

Figure 2. An activity related to the addition rule with tailored feedback

A key design feature of the OLI environment is that as students work through the course, the system collects real-time, interaction-level data about student use and learning. The richness of the data provides the instructor with a clear picture of the students’ knowledge state – individually and as a class. These data are analyzed and summarized in the *Instructor Learning Dashboard* which presents instructors with a measure of student learning for each learning objective and helps instructors identify concepts and skills that students are learning well and those that students are struggling with. As a result, an instructor can spend class time more effectively by focusing on the students needs.

Figure 3 shows a view of the Instructor's Learning Dashboard. Each bar shows the proportion of students who have demonstrated high (green), moderate (yellow), or low (red) levels of learning for the corresponding learning objective. (Gray indicates students have not worked with the system enough for these estimates to be made.) The instructor can "drill down" from this view to get more detailed information on how individual students are doing or which sub-skills within a learning objective students are struggling with.

Figure 3. View of Students' Learning via the *Learning Dashboard*

It is important to mention that beyond feedback to the students and to the instructors, the data collected by the OLI system drives two additional feedback loops. Course developers can use these data to assess how students are using the material and the impact of their use patterns on learning outcomes. Based on this analysis, course developers are able to iteratively improve the course for future students. Also, learning science researchers use the richness of the data to create and refine theories of human learning.

ASSESSMENT

The OLI statistics course is perhaps the most systematically studied of all online university courses to date and its effectiveness has been proven in a variety of higher education settings, both in the online-only and hybrid formats (Lovett, 2016). In fact, according to Winitzky-Stephens et al. (2017), the OLI statistics course is the subject of the only studies examining the effect of an interactive online course on learning outcomes that utilized randomization.

Studies at Carnegie Mellon University (CMU)

As part of our work in designing the course, its effectiveness for student learning was researched in a series of five studies conducted between Spring 2005 and Spring 2010. The design and results of these studies were previously reported in detail and are summarized below.

The goal of our first two studies was a "do no harm" test of the stand-alone version of the OLI Statistics course (i.e., students' learning would not be harmed relative to taking statistics in a traditional face-to-face setting). Results showed that when the OLI statistics course was used as a stand-alone course, student learning gains were at least as good as in a traditional, instructor-led course (see Lovett, Meyer and Thille, 2008).

In our next three studies we tested whether learners using the OLI course in hybrid mode, where the students meet with the instructor regularly (though less frequent than in the traditional course), while also using the online modules and assignments of the OLI Statistics course, would learn the same amount of material in a shorter time than students in traditional class formats. To emphasize the difference between these two conditions, the students who used the OLI course in hybrid mode met with the instructor two times per week for an eight-week mini-semester whereas the traditional/control students met with the instructor four times per week (three for lecture and one for a computer lab session) for a full 15-week semester. The results of all three studies were striking: students who used the OLI Statistics course in the hybrid (accelerated) mode demonstrated significantly better learning outcomes as compared to students with traditional instruction (see Lovett & Meyer, 2014). Usually, that kind of effectiveness would be expected only as result of individualized human tutored instruction (e.g., Bloom, 1984). And yet in this case students who met with an instructor for less the two hours of class per week demonstrated this effect. Furthermore, students' logs showed that the OLI students in the accelerated mode spent no more time studying outside class than the traditional students and that there was no significant difference in retention between students in the two conditions (see Lovett, Meyer, & Thille, 2010). We posit that what underpins the success of the accelerated hybrid mode is the preparation of both the students and instructor informed by OLI's feedback loops. Students attended class after actively engaging with the material, receiving timely and targeted feedback, and reflecting on their own knowledge. Equally as important, thanks to reports generated by the Learning Dashboard, the instructor spent class time more effectively by targeting topics that students were struggling with.

The ITHAKA Study

One person that took note of the results of the accelerated studies was (now, sadly, the late) William Bowen who almost 50 years earlier had expressed concern about the "cost disease" in higher education. A leader in higher education for more than half a century (including president emeritus of Princeton University) Bowen was quoted saying: "I have been on record for some time as being skeptical about the likely effects of productivity in higher education of various new technologies… But the evidence…about the work at Carnegie Mellon has caused me to re-think my positions…" (Thille, 2012). Bowen, who at the time was the head of the consulting group ITHAKA S+R, decided to conduct his own national study in which students from six public university campuses participated in a randomized trial, comparing the OLI Statistics course taught in hybrid mode to a traditional Statistics course (Bowen, Chingos, Lack, and Nygren, 2014). Students enrolled in introductory statistics at each of the institutions were invited to participate in the study, and those who volunteered were randomly assigned to the hybrid or traditional condition. In the hybrid sections, students met once per week with their instructor and for the rest of their studies completed assigned work in the OLI Statistics course. None of these hybrid sections, however, was conducted in an accelerated format. So the hypothesis being tested was whether the OLI course taught in hybrid mode with far less instructor face-to-face time could produce equal or better learning gains than the traditional version of the course.

Figure 4 shows the results of the hybrid vs. traditional conditions on three key dependent measures: final exam scores, post-test scores on the Comprehensive Assessment of Outcomes in a First Statistics Course (CAOS) test of statistical literacy (delMas, Ooms, Garfield and Chance, 2007), and pass rates. In all three cases, there were no significant differences between conditions, indicating that the hybrid students learned as much as the traditional students even though they participated in fewer class meetings per week. Furthermore, the researchers found that the hybrid

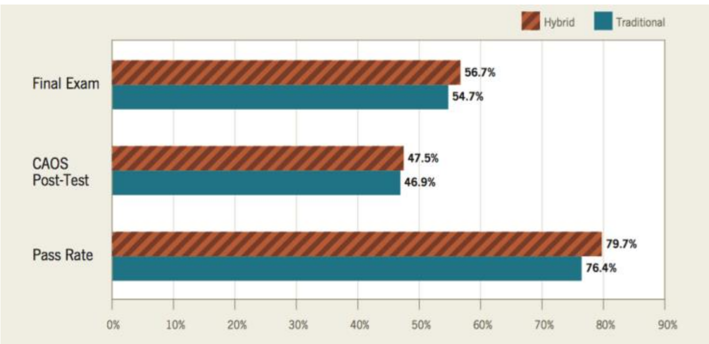

Figure 4. Student learning outcomes for each condition. Reproduced from Bowen, 2012.

students spent about 25 percent less time on the course – including class time and out-of-class time – compared to traditional students.

Bowen follow-up the study with a simulated cost analysis associated with shifting from traditional face-to-face instruction to the hybrid model. The analysis suggested savings in compensation costs alone ranging from 36 percent to 57 percent when the traditional teaching mode relies on multiple sections, and 19 percent when the traditional teaching mode relies on one large lecture broken into small discussion sections (Bowen, Chingos, Lack, and Nygren., 2014). Bowen added that the analysis underestimates substantially the potential savings from moving toward a hybrid-online model because it does not account for space costs as well as reductions in the “time costs” incurred by students (Bowen, 2012).

DISCUSSION

While Bowen’s research was in the context of statistics education, he viewed the ITHAKA study more broadly as assessing the educational outcomes associated with a prototypical highly sophisticated interactive online course in which machine-guided instruction can substitute for some face-to-face instruction (Bowen, Chingos, Lack, and Nygren 2014). Bowen therefore interpreted the results of his study and their implications in the context of higher educational in general.

First, Bowen cited the results of the ITHAKA study along with the cost analysis as *the* piece of evidence to justify his claim that technology-enabled instruction (under the right circumstances) was finally at a point that we could take on the ‘cost disease’ in higher education. Namely, providing access to high quality education while at the same time increasing productivity.

Second, the fact that the students “paid no price” in terms of pass rates or other learning outcomes for taking a hybrid course calls into question the most common reason given by faculty and deans for resisting the use of online instruction: “We don't want to try this because it will hurt our students.” A veteran statistics professor at Maryland's Towson University who taught a hybrid section in this study, was initially among the skeptics. Afterwards, she is quoted as saying "I walked away with a much more positive outlook for online courses", and added that most students came away with a "deeper understanding” (Lovett and Meyer, 2014).

Third, the finding of no statistically significant difference in standard measures of learning outcomes between students in the traditional condition and students in the hybrid-online format condition was consistent across sub-groups of what was a very diverse group of students. For example, roughly half the students in the ITHAKA study came from lower-income households, and roughly half were first generation college students. The group was roughly evenly divided between students with college GPA above and below 3.0, and fewer than half the students were white. This challenges the hypothesis that only exceptionally well-prepared, highly achieving students can succeed in online settings (Bowen, 2012).

Bowen report documenting the results of the ITHAKA study gained national recognition, and has not only encouraged many new instructors to explore ways to adopt or adapt the OLI Statistics course and platform in creative ways to support their own teaching, but has also placed statistics education at the forefront of the discourse on how technology-enhanced instruction can be used to improve learning outcomes in the face of limited resources.

SUMMARY

The OLI Statistics course was originally developed to allow students to learn the material independently without the guidance of an instructor, and it is still offered in this model through Carnegie Mellon. However, it soon became clear that the fact that the course was designed as a stand-alone course – making knowledge structures explicit and following as many principles of learning as possible – promoted its striking success when used in hybrid form (Lovett, Meyer, and Thille 2008). The results of the ITHAKA national study along with its cost analysis, have drawn the higher education community’s attention to OLI, and suggested more broadly that adopting hybrid model of instruction in large introductory courses has the potential to provide quality instruction while significantly reducing costs – indicating that Baumol and Bowen’s eponymous “cost disease” is curable with the right tools.

The course team is delighted that the OLI Statistics course is used by thousands of students every semester and that it pedagogically supports instructors of introductory statistics. In fact, in his article "Helping Community College Math Instructors Teach Statistics Effectively", Teachout (2016) recommends incorporating the OLI Statistics course in place of a traditional textbook. It is also gratifying that the OLI Statistics course has played such a prominent role in the national discussion and research about best practices and effective use of technology-enhanced instruction in higher education. The process of designing the OLI Statistics course, assessing its effectiveness, and supporting its users has truly encapsulated the late professor of Carnegie Mellon University and Nobel Laureate Herbert Simon's vision that "improvements in post secondary education will require converting teaching from a 'solo sport' to a community based research activity."

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