# USING CARNEGIE MELLON'S OPEN LEARNING INITIATIVE (OLI) TO SUPPORT THE TEACHING OF INTRODUCTORY STATISTICS: EXPERIENCES, ASSESSMENTS, AND LESSONS LEARNED

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*As part of the Open Learning Initiative (OLI) project, Carnegie Mellon University was funded to develop a web-based introductory statistics course, designed to support students to effectively learn Statistics without an instructor. Numerous carefully designed studies have shown, however, that the course is most effective when used in a hybrid instructional model, i.e., face-to-face teaching plus online learning. We discuss the design features that make the OLI Statistics course "work," present the most current assessment results, and describe different ways in which instructors have used the OLI materials to support their Statistics courses. In addition, we discuss how the OLI platform can be used by instructors to create their own materials.*

## INTRODUCTION

As part of the Open Learning Initiative (OLI) project, Carnegie Mellon University was funded by The William and Flora Hewlett Foundation to develop an online introductory statistics course. The Foundation's interest was in providing open access to high-quality post-secondary educational materials to those who otherwise would be excluded or not encouraged to pursue higher education (Smith & Thille, 2004). The course was developed by a team of learning scientists, statistics faculty members, 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 principles from learning science (e.g., Ambrose et al., 2010). For example, based on research showing the importance of "connected" rather than "fragmented" knowledge, 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. Figure 1 shows the version of this "big picture" as students see it when starting unit 2 of the course.

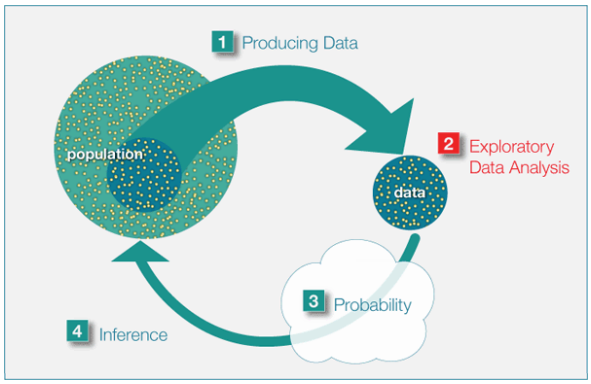


Figure 1. OLI Statistics course highlights the "big picture" of Statistics to students

To incorporate the principle of deliberate practice (Deslauriers, Schelew, & Wieman, 2011; Ericsson, Krampe, & Tesch-Romer, 1993), the course was designed to include repeated opportunities for practice and feedback on each of the skills and concepts students need to learn to achieve the course objectives. For example, "did I get this?" questions and "learn by doing" activities appear throughout the course, prompting students to check their comprehension and put their new knowledge to the test by applying it in more and more complex situations. Moreover, for each of these activities and questions, students can ask for help (in the form of a hint) and receive

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immediate feedback specific to their response. From the students' perspective, this interaction shares some of the features of studying with a human tutor, so we call these activities "mini-tutors." This is rather different from what tends to happen in a traditional course: students attend lecture on one day, work on homework several days later, and then receive feedback a week or more after that. Figure 2 shows a question in the course related to correlation and causation and the tailored feedback that the system provides when the student answers this question incorrectly.

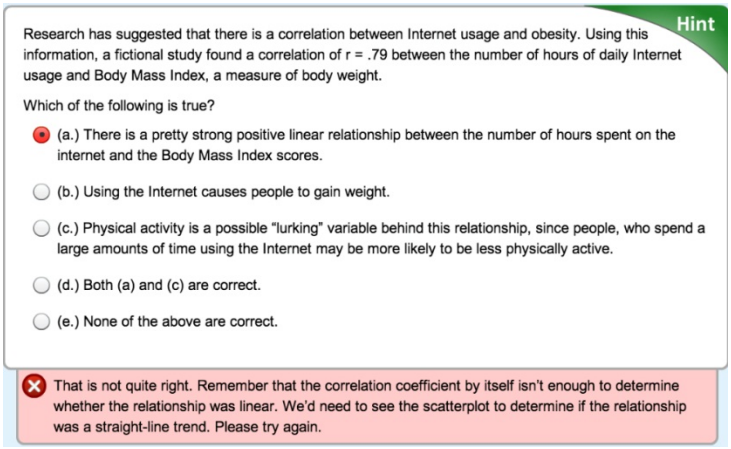


Figure 2. An activity related to correlation and regression with tailored feedback

It is important to mention that within the OLI statistics course, not only do students receive tailored feedback based on their actions in the course, but instructors receive detailed feedback on the progress and performance of their students – individually and as a class. As students work through the OLI course, the system collects real-time, interaction-level data on how they are learning. These data are analyzed and aggregated according to the target skills and learning objectives of the course and then presented via a *Learning Dashboard* so that instructors can identify the concepts or skills where students are learning well or having difficulty.

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 on which sub-skills within a learning objective are giving students the most trouble. Instructors can also use the Learning Dashboard to see how students responded to particular activities and questions.

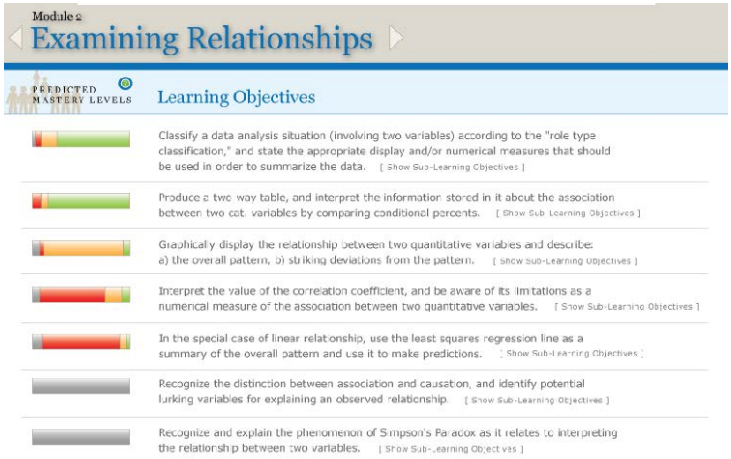


Figure 3. View of Students' Learning via the *Learning Dashboard*

## ASSESSMENT

*Previous Learning Studies*

As part of our work in designing the course, we wanted to study its effectiveness for student learning. Our first two studies, conducted in Spring 2005 and Spring 2006 represent a fairly simple "do no harm" test of the stand-alone version of OLI-Statistics (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 in the way as a stand-alone course, student learning gains were at least as good as in a traditional, instructor-led course (see Lovett, Meyer & Thille, 2008).

Our next studies (Spring 2007 and Spring 2009) were in search of an effective blend of face-to-face instruction with an online course. The idea here was to have students work through a specified piece of the OLI statistics course materials on their own first and then have the instructor provide additional face-to-face instruction to address any relevant areas of difficulty. Results showed that students who used the OLI Statistics course in this hybrid mode were able to learn better and in half the time (accelerated) as compared to students with traditional instruction (see Lovett, Meyer, & Thille, 2010). Usually, that kind of effectiveness or efficiency effect would be the result of individualized, human tutored instruction (e.g., Bloom, 1984). And yet, we achieved these results with close to 50 students in a class that met for less than two hours per week. The mechanism we posit for this result is the preparedness of both the students and the instructor, as facilitated by the OLI-Statistics course. Students attended class after actively engaging with the material by answering questions, receiving feedback, and reflecting on their own knowledge. And, the instructor came to class fully aware of what the students were struggling with.

Following these encouraging results, our next step was to expand the study of the course's effectiveness with other (less experienced) instructors and other student populations.

*Expanding the Assessment*

The latest study we have conducted on the OLI statistics course had a similar study design to our previous work, but this time we controlled for possible "instructor effects" by comparing two sections – "adaptive, accelerated" versus "traditional, control" – that were taught by the *same* instructor. Moreover, this instructor was unfamiliar with the OLI statistics course and was completely new to teaching in hybrid mode with an online course.

The number of students in the adaptive, hybrid section was 40 and the remaining 129 students in the traditional section served as our control. Looking at several factors (gender, major, year in school), the two groups were not significantly different. In addition, comparing the two groups' pretest scores on the Comprehensive Assessment of Outcomes in a First Statistics Course (CAOS) test (delMas, Ooms, Garfield, & Chance, 2006) were not significantly different.

To reiterate the differences between the two conditions, the adaptive/accelerated students 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. Students in the adaptive/accelerated section worked through assigned parts of the OLI statistics course as homework before each class. This allowed the instructor to review students' progress via the Learning Dashboard and then adapt his teaching to meet the students' current needs. In contrast, students in the traditional/control section completed traditional problem sets, and lectures were not adjusted. Both groups of students took similar in-class exams and a final exam, and both groups took the CAOS test as a post-test.

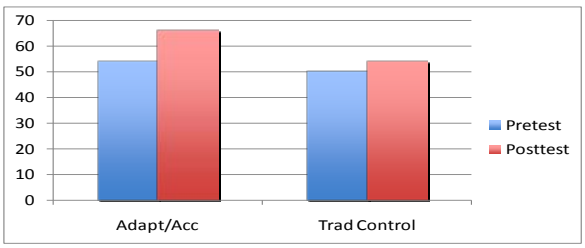


Figure 4. CAOS results for accelerated OLI-Statistics versus traditional control

We used the CAOS test results from the beginning of the semester (first week of class) and at the end of the course (week 8 for the adaptive, accelerated section and week 15 for the traditional, control section) as our main dependent measure, since the in-class exams were not formally matched or measured for validity and reliability. Figure 4 shows the pre- and post-test scores for the two groups. Using gain scores (post-test minus pre-test) as the depending measure, the adaptive, accelerated section had significantly higher gains than the traditional, control. Interestingly, the traditional, control section's gain scores did not differ significantly from zero.

Given the positive results of this study combined with our prior work, we have a consistent set of results from three accelerated learning studies: whenever we compared a traditional introductory statistics course (taught with three lectures, homework problems, and a computer lab each week) to an adaptive, accelerated version of the course (combining two class meetings and homework from the OLI statistics course), students in the adaptive, accelerated course had significantly greater learning gains on the same material after spending about half as much time.

Since all three studies were conducted at one university, there were still questions about whether these results would generalize to other settings. In separate work conducted by independent researchers, 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, & Nygren; 2012, 2014). As in our studies, 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 5 shows the results of the hybrid vs. traditional conditions on three key dependent measures: final exam scores, CAOS Post-Test scores, 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 hybrid students spent about 25% less time on the course—including class time and out-of-class time – compared to traditional students.

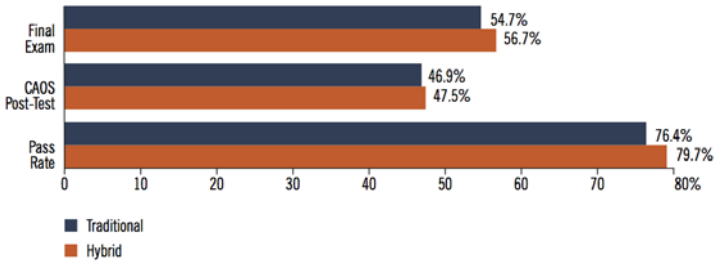


Figure 5. Student learning outcomes for each condition in Bowen et al. (2012). Reproduced from Bowen et al, 2012.

One of the study's architects, William Bowen, is quoted as saying: "The most important single result of our study: It calls into question the position of the skeptic who says, 'I don't want to try this because it will hurt my 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".

Because the report documenting the results of this study gained some national recognition, many new instructors were interested in exploring ways to adopt or adapt the OLI Statistics course and platform in creative ways to support their own teaching.

## OTHER WAYS TO USE OLI IN TEACHING STATISTICS

Beyond the hybrid model explored in the studies above, there is a variety of ways in which programs and instructors can make use of the OLI Statistics course and platform to support their specific pedagogical needs. In this section we will present three specific cases.

### *Using the OLI-Statistics in Preparation for Graduate Studies*

In their first semester of the Master in American Government at Georgetown University, students are required to complete the course, Analysis of Political Data. In one semester, the students need to cover all the material covered in a traditional introductory statistics course, including multivariate regression, analysis of complex survey data, and principles of research design. Over the years, the instructor has found it to be impossible task without rushing through the material. This situation was particularly challenging to the students many of whom have been out of school for several years and/or are not quantitatively inclined.

To solve this problem, the instructor decided to have the students go through and complete on their own all the activities in the Exploratory Data Analysis module of the OLI statistics course during the summer prior to the start of the program. Not having to use valuable lecture time on this material, most of which consists of GRE General Test-level quantitative skills, allowed the instructor to spend more time on important skills and methods. Furthermore, the students unanimously agreed that having this "refresher" prior to starting the program has been valuable not only as a preparation for the data analysis course but more generally it helped in easing them into the academic demands of a graduate program. In addition, in some parts of the course itself, the instructor used the OLI Statistics course in the hybrid model described earlier. Taking advantage of the students' active and deep engagement with the material and the detailed analytics that the course provides to the instructor allowed him to use class time more effectively and efficiently.

### *Using the OLI-Statistics Course as a 'Distant-Learning' Summer Course*

Another program benefitting from the OLI Statistics course is the Master in Human Computer Interaction (MHCI) at Carnegie Mellon University. In this rigorous program, students are required to have knowledge of statistics prior to starting project work in the second semester. Due to the packed course load during the first semester, the program tried offering a week-long crash-course in statistics either in the week prior to the beginning of the program (when students are occupied with getting settled in a new city) or in the week prior to the start of the spring semester (significantly shortening winter break). Unfortunately, these attempts were unsuccessful.

In recent years, the program has started taking advantage of the OLI Statistics course and is offering it as a 6-week summer course prior to the start of the program. The format is a combination of distance learning and the hybrid model. Students go through the OLI-Statistics course, leaving their so called "digital breadcrumbs" for the OLI system to collect and present to the instructor, and then face-to-face class time is replaced with WebEx conference meetings. The course has been running in this format for three years and been highly praised by the students as valuable to their success in the MHCI program.

### *Using the OLI Platform to Develop New Materials*

The School of Foreign Service (SFS) at Georgetown University offers a required course in statistics for international politics, which meets for only one 75 minutes lecture per week and one smaller recitation-type lab session taught by a teaching assistant (TA). The course covers more material than the typical introductory statistics curriculum and the lectures are fast-paced. It is therefore the role of the labs to enhance the course objectives by giving the students a chance to apply the lectures' material in the context of real international politics data. In the current TA-led labs, the students do not get a chance to "get their hands dirty with data" and course evaluations reveal that students have had a hard time making the connection between the lab experience and lecture material. In addition, students come to lecture with varying levels of preparedness, which is due to large variability in the TAs' pedagogical abilities (Meyer & Patel 2014).

In an ongoing project, the SFS is using OLI learning environment as the platform for designing and creating a more engaging, interactive, and uniform lab modules that can more efficiently support the lectures, and enhance the course objectives. So far, six modules have been

created that cover introduction to the software Stata, exploratory data analysis, and interval estimation. Initial qualitative assessment revealed that the majority of students prefer the OLI-based labs to the TA-led labs but prefer not letting go of the "human component" and have a TA available during the lab to answer questions.

## SUMMARY

The OLI Statistics course's original intent was to support online individual learning with no instructor in the background. However, it soon became clear that the fact that it 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). Several studies within Carnegie Mellon demonstrated the course's effectiveness in this learning model, but it was the national randomized trial conducted by Bowen, Chingos, Lack, and Nygren (2012) that has drawn the higher education community's attention to OLI by extending these results beyond the Carnegie Mellon context. As William Bowen pointed out, an additional important outcome of the study was that after using the OLI Statistics course, instructors who were skeptics of online education began to realize that, if carefully designed, online materials can support teaching and lead to a more efficient and deeper learning processes.

Beyond leading to encouraging learning outcome results, the national study suggested that the OLI approach might help address the challenge that many academic institutions are facing – namely, providing effective instruction under limited resources. That study's researchers estimated that, once the software investment is made, hybrid online courses could cost half what conventional classes do. Finally, impressed by the study's results, many instructors and academic program were inspired to find creative ways to use the OLI statistics course and platform to support their specific pedagogical and curricular needs. We are gratified that the OLI statistics course (and other OLI courses) are currently used by thousands of students every semester and that instructors are exploring new ways of incorporating online courses into their teaching.

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