Experiential Undergraduate Operations Management Course Engages Students

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This article describes an experiential operations management course for undergraduate business students at a large public university. This course includes computer labs and "hands-on" group activities, which students find both interesting and helpful in understanding the material. We discuss strategies for success in implementing such a course as well as benefits and challenges of the course. To evaluate the effectiveness of this approach, we compare it to a typical traditional lecture format using multiple assessments approaches including exams, teaching evaluations, and instructor observations. We also conduct student surveys to understand how the students perceive the activities. The findings show that new format of the course engages students while improving student performance compared to that of traditional lectures.

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I. INTRODUCTION

Teaching operations management to undergraduate students has several challenges. Operations management requires students to apply critical thinking skills and use math and statistics to solve mathematical problems, which can be challenging for many students. Many students have little relevant work experience and lack context for understanding operations management and how it impacts their lives.

To address these issues, the authors developed a new version of a required undergraduate operations management course that is primarily taught in a traditional lecture format. This new version of the course includes computer labs and "hands-on" small group activities designed to create connections to the real world and increase student engagement. The activities usually follow mini-lectures providing students with relevant operations management concepts that form the foundational knowledge basis for the activities. We specifically chose activities that the students could relate to from their own experiences and structured these activities to provide guidance to students while allowing them to be involved with such things as gathering data and defining parameters of the problem.

Three instructors each taught one section of this new version of the course in three different semesters (a total of nine sections). We started the implementation of the activities in the 2017 summer term, and after improving and streamlining the activities, we started testing the effectiveness of these activities in the fall of 2017. During that semester, each of the instructors taught the new version concurrently with the typical lecture format class, enabling us to directly compare the two groups of students across all three instructors. For simplicity, we label this new approach the "lab-based" version and label the traditional approach as "lecture-based". In the spring term of 2018, two of the instructors continued teaching one section of each version, whereas the other instructor taught only the lab-based version.

We used multiple approaches to assess activity effectiveness, including exams, surveys, teaching evaluations, and instructor observations. Exam results were used to assess student learning outcomes, and the results suggest that, on average, student performance is better with the lab-based class than with the lecture-based class. More specifically, we find with statistical significance that students are better at identifying the appropriate methodology and executing the methodology. Survey results indicate that a large majority of the students in the lab-based class feel positively about their experiences with the labs and the activities. Teaching evaluations show that the lab-based class satisfies student learning expectations at least as well as the lecture-based class. Furthermore, the professors teaching the course found the class atmosphere improved with students being more engaged with the course material in the lab-based class than they are in the traditional lecture class.

This paper is organized as follows. In Section 2, we review the related literature. Section 3 provides background information on the subject course. Section 4 outlines our lab-based operations management course and gives details for two computer lab activities and two in-class activities. We discuss strategies for success in Sections 5. In Section 6, we assess the effectiveness of the activities and conclude with future directions in Section 7.

II. LITERATURE REVIEW

Snider and Balakrishnan (2013) breakdown the different learning methods into two broad categories: passive learning and active learning. An example of passive learning is the traditional lecture format classes, in which students are passive learners, as they would merely be listening or taking notes. The authors further classify active learning methods as either experiential or non-experiential. With experiential active learning methods, the students have a chance to reflect on their direct experience and may acquire abstraction skills. Case studies are a non-experiential learning activity because they do not allow students to directly experience the decision-making process and instead assist the students in contextualizing concepts. The authors categorize experiential active learning approaches further as semi-structured or loosely-structured. For example, short classroom activities are considered semi-structured and longer, more complex ones loosely-structured.

We created both types of active learning opportunities, experiential and non-experiential, for our lab-based course. An example of a non-experiential active learning activity would be a word problem that students work out in groups. Others are experiential activities, which can be semi-structured or loosely-structured depending on how much lecture time an instructor would like to dedicate to these activities in place of content coverage. An example would be an activity for which students gather the relevant data themselves (semi-structured) and perhaps even define what the problem is about and the necessary parameters with instructor guidance (loosely-structured).

Apart from the discussion of active and passive learning activities, many researchers study Problem Based Learning approaches (PBL). Because some of our activities fall into this category as well, we briefly review the relevant literature. In PBL, active learners address an ill-structured problem and engage in mostly self-directed learning to solve the problem. In this sense, according to Snider and Balakrishnan's framework of learning approaches, PBL falls under the loosely-structured experiential active learning category. PBL has been used widely in medical education for some time but more recently gained recognition in business education (Carriger 2015).

There are challenges in effectively implementing a PBL approach, which leads to not only improved problem solving skills but also to greater knowledge acquisition. Carriger (2015) reviews 90 studies measuring the effectiveness of PBL approach in medical, engineering, and management fields. The authors conclude that in comparison to lecture-based approaches to education, students' problem-solving skills improve but their knowledge acquisition does not. Because PBL activities are lengthy and open ended, instructors have less time for content coverage; hence, students' performance in subsequent exams may suffer.

Snider et al. (2017) developed a 30-minute PBL activity and initially found that students had lower performance compared to students in a traditional lecture course. They were able to overcome this issue by increasing the guidance provided to the students. They found that students' performance previously achieved through traditional lecture did not suffer while student engagement improved. Perhaps what Snider et al. (2017) experienced in their implementation of PBL is best summarized by Kirschner et al. (2006). These authors survey the results of well-designed controlled studies and conclude that there is support for direct, strong instructional guidance rather than constructivist-based minimal guidance during the instruction of novice to intermediate learners. The authors report that even for students with significant prior knowledge, strong guidance while learning is found to be as effective as unguided approaches.

Another issue with implementation of the PBL approach is the assessment of learning outcomes. Macdonald (2005) proposes that assessment methods should be modified when a PBL approach rather than a traditional lecture format is being utilized in order to effectively measure the learning outcomes targeted by the PBL approach. On the other hand, Bamford et al. (2012) conclude that assessing students' performance using problem-based assessment in an operations management course proves problematic compared to a traditional assessment method such as a final exam. This stems from the fact that PBL activities occur in groups, which makes it more difficult for the instructor to assess the performance of an individual, as these activities appear to be more advantageous to poor performers. Johnson et al. (2002) introduced problem based learning sessions into a traditional lecture format for a third year nutrition science class. To assess students' critical thinking skills individually they included a mini case study within the final exam. Therefore, their assessment component not only mirrored the process used during the PBL program but also was able to classify students more effectively on their performance.

Some of the key potential benefits of a PBL approach are improving team skills, critical thinking skills, and the ability to frame a problem, skills which are harder to assess but are highly valued by employers (Maggitti 2018; Adams 2018; Ghannadian 2014). Hartman et al. (2013) assess some of the softer skills that may be improved through the implementation of PBL activities, specifically tolerance for ambiguity, problem-focused coping, and emotion-focused coping. The authors report improvement only on emotion-focused coping and find a negative influence on tolerance for ambiguity. Kanet and Barut (2003) share results from a longitudinal study in which graduate business students complete a project with companies. After analyzing student survey data the authors report the project improves not only problem solving skills but also communication skills and confidence levels.

One positive outcome reported by researchers is the general increased levels of engagement of students with the material. Snider et al. (2017) and Kanet and Barut (2003) report high levels of student satisfaction with their respective PBL activities. Piercy et al. (2012) survey students' perceptions and preferences of experiential learning methods in small and large operations management courses; the authors conclude that both groups of students perceive the business simulation game used in the class positively.

Naik (2011), on the other hand, witnessed mixed results from implementing a supply chain simulation games in an introductory operations management course. While most students enjoyed playing the games and many felt their operations management skill levels improved, a significant percentage of students thought the benefits were not worth the time and effort. Their findings indicate that a more balanced approach is key to successful implementation of PBL activities.

Indeed, Carriger (2016) suggests that a hybrid approach of lecture and PBL may offer a balance of problem solving skills and content knowledge. In an undergraduate business course in human resources, he compared the effectiveness of three learning approaches: pure PBL activities, lecture-based instruction, and a hybrid approach that used mini-lectures as well as short PBL activities. He found that the hybrid approach led to more knowledge acquisition and critical thinking skills, particularly for students later in their academic careers. Additionally, he found that students responded more positively to the hybrid approach than either the lecture-based instruction or pure PBL approach.

An alternative to ill-structured PBL activities that take considerable amount of class time are semi-structured experiential activities; these can lead to both increased engagement levels from students and improved softer skills as gained through ill-structured PBL activities. However, given that the problem is more clearly defined, such activities are not likely to improve students' ability to frame a problem. Carriger's (2016) hybrid approach supports the case for semi-structured activities as an alternative to the pure PBL approach, especially given the mixed results others report with the latter.

Likewise, the use of operations games in teaching operations management is cited widely in the literature. Such games can be considered either semi-structured or ill-structured experiential activities; the difference is not clear-cut and depends on the implementation details. Typically, the longer an activity the more ill-defined it can be, especially if the students are completing the activity outside of the class hours such as for semester long projects.

We do not classify the following operations games as semi or ill-structured but only summarize them according to the covered topics. Olsen (2018), Mitchell et al. (2014), Fish et al. (2012), and Coy (2016) cover quality management and statistical process control concepts through various games. Klassen and Willoughby (2003), Robb et al. (2010), Meyer and Bishop (2016), and Umble and Umble (2013) incorporate inventory management games into their classes. Vliegen and Zonderland (2017) and Snider and Southin (2016) both utilize in-class capacity management exercises. Snider et al. (2017), Klotz (2011), and Piercy (2010) utilize production games to introduce production line design and assembly line balancing concepts. Ashenbaum (2010) uses a brief just-in-time exercise. Tucker and Lefton (2015) incorporate a game into their production class where students face operational failures, devise workarounds, and analyze the trade-offs. Pendegraft (1997) and Cochran (2015) utilize the game "Lego My Simplex" devised by the former author to illustrate the modeling concepts for linear programming. Cholette and Roeder (2012) introduce a hands-on sustainability activity completed within a spreadsheet environment during the lecture. Students analyze the operations of a company and the resultant energy usage and greenhouse emissions.

Some of the published papers we reviewed cover multiple topics through the same game or project. Miyaoka (2005a) utilizes Legos to teach commonly required topics in operations management courses, such as push and pull production systems, project management, and quality management. Gray (2011) engages students in learning various production and quality concepts using a hands-on project. The students complete a project outside class for which they design and manufacture a product made only of paper. Roeder and Miyaoka (2015) and Miyaoka (2005b) discuss the successful use of two computer simulations in teaching operations management courses at both the undergraduate and graduate levels. In the Littlefield Technologies Capacity Management game, students can apply their newly gained knowledge in forecasting, capacity planning, and queuing theory. Wright (2015) used a semester long game that allows teams of students take on the role of a decision maker for a manufacturing firm to determine process design and layout, scheduling, product mix, quality management, and material ordering in order to maximize profit.

Some of the authors of operations games assess the effectiveness of their teaching methods through exams and/or surveys. Meyer and Bishop (2016) and Ashenbaum (2010) use pre-exercise and post-exercise tests to measure the effectiveness of their activities. Klotz (2011) shows that student performance improves when they do the exercise a second time. Snider et al. (2017) and Fish et al. (2012) use their activity in one class and not in another class and compare test results of the two groups. Klotz (2011), Klasssen and Willoughby (2003), Miyaoka (2005b), and Cholette and Roeder (2012) survey the students on their perception of the effectiveness of the games in their learning.

Our paper is different from the papers on operations management activities discussed above which tend to focus on a single activity or set of activities in a particular topic area. We present an operations management course with numerous hands-on, semi-structured and loosely-structured experiential learning activities embedded throughout the course, combined with relevant mini-lectures. We find that this lab-based format creates an environment of high student engagement and collaborative learning that extends beyond the individual activities. In addition, we compare our lab-based format to the traditional lecture format using exams and teaching evaluations from three different instructors who have taught both formats in the same semester, creating a consistent comparison base of the two formats.

III. BACKGROUND

The subject course in this study is titled Operations Management and is a required course for all undergraduate business majors in a large public university. While instructors have some leeway to cover additional subjects, the required topics in this course include forecasting, capacity planning, inventory management, linear programming, project management, and quality management. Students must obtain at least a C- in this course in order to take other required business courses. Many of them, however, struggle with the math, statistics, and critical thinking required in this course and approximately 20% of students have to repeat the course.

Typically, the course has about 55 students per section and is delivered in a format that is mostly lecture with some active learning activities, mostly non-experiential, like working out textbook problems in class and going to the computer lab to learn how to create forecasts in Excel. Starting in the summer of 2017, the department developed and started offering three sections per semester of a lab-based version of the course that includes experiential activities in the computer lab and in the classroom. Currently, three faculty members have each taught one section of the lab-based course in Summer 2017, Fall 2017, and Spring 2018 terms (for a total of nine sections) with each section having between 30 to 40 students.

IV. LAB-BASED OPERATIONS MANAGEMENT COURSE

The authors have identified activities for each of the six required course topics: forecasting, capacity planning, inventory management, linear programming, project management, and quality management. While we developed most of the activities, a couple activities came from other sources. Table 1 summarizes the activities in each of the topic areas, noting sources as appropriate. According to the classification of learning methods by Snider and Balakrishnan (2013) - previously summarized in the literature review section – all of the activities listed in Table 1 fall into the active learning approach category. Furthermore, all but one are experiential learning activities.

In developing this course, we follow approaches for creating student-centered and engaged learning environments found in the literature. In particular, we mention two articles here. Land and Hannafin (2000) discuss how, in a learner-centered environment, the learner actively constructs meaning. They suggest approaches such as incorporating familiar real-world problems and creating social interactions from which learners evaluate and negotiate. A recent article by Rhodes (2017) discusses creating engaged learning environments for operations and supply chain management courses and identifies six factors: well-designed learning strategies, appropriate space, value-added technology, support, engaged facilitators, and engaged learners. In addition, they identify ten relevant tools and techniques for engaged learning. Of these ten tools, we have incorporated five of them into our lab-based course: relevant learning, active learning, critical thinking, collaborative learning, and simulation.

TABLE 1. LAB-BASED COURSE ACTIVITIES

Topic Area	Activity		Description	Active Learning Category	Time Required (Minutes)
Forecasting	1	Time Series Data Patterns	See Section 4.1	Loosely-structured experiential	30
	2	Time Series Forecasting	See Section 4.2	Loosely-structured experiential	45
	3	Linear Regression Forecasting	Students analyze data for correlation and create an appropriate regression model.	Non-experiential	45
Capacity Planning	4	Break-even Analysis with Step-Function Costs	Students consider a business opportunity of offering trips to college students where they determine breakeven points for different capacity options that they identify from hotel and car rental price quotes.	Semi-structured experiential	30
	5	Overbooking a Flight Using Decision Analysis	See Section 4.3	Semi-structured experiential	45-60
Inventory Management	6	He Shoots, He Scores	Students make ordering decisions in this role-play simulation game by Klassen and Willoughby (2003)	Loosely-structured experiential	60
	7	Overbooking a Flight Using the Newsvendor Model	See Section 4.4	Semi-structured experiential	30
Project Management	8	Wedding Planning Using Post-it Notes	Students use Post-it Notes to organize a list of activities for planning a wedding into a network diagram.	Loosely-structured experiential	30
	9	MS Project Wedding Planning	Students use their network diagrams from the Wedding Planning Post-it Notes activity to create a network diagram in MS Project.	Semi-structured experiential	45-60
Linear Programming	10	Lego of My Simplex	Students find the optimal mix of tables and chairs given a limited supply of materials, based on Pendergraft(1997)	Semi-structured experiential	30-45
Quality Management	11	Data Collection on Cookies	Students collect data on a sample of cookies. Using the data, students compute descriptive statistics.	Semi-structured experiential	30
	12	Statistical Process Control Charts on Cookie Data	Students use the cookie data to create statistical process control charts.	Semi-structured experiential	60-75

TABLE 2. ACTIVITIES IMPLEMENTED IN LAB-BASED SECTIONS

		Instructor 1			Instructor 2			Instructor 3		
Topic Area	Activity	Sum 2017	Fall 2017	Spr 2018	Sum 2017	Fall 2017	Spr 2018	Sum 2017	Fall 2017	Spr 2018
Forecasting	1	X	X	X	X		X	X	X	X
	2	X	X	X	X		X	X	X	X
	3	X	X	X		X	X			
Capacity Planning	4	X	X	X				X	X	
	5						X	X	X	X
Inventory Mgmt	6				X	X	X			
	7							X	X	X
Project Mgmt	8	X	X					X	X	X
	9				X	X	X	X	X	
Linear Prog	10	X	X	X	X	X	X	X	X	X
Quality Mgmt	11	X	X	X	X	X	X	X	X	X
	12	X	X	X	X	X	X	X	X	X
Total		8	8	7	7	6	9	10	10	8

This lab-based course has been taught a total of nine times from Summer 2017 to Spring 2018, and Table 2 shows the faculty teaching this lab-based course use some subset (anywhere from six to ten) of the activities presented.

To illustrate the approach used in class, we chose a subset of the activities from Table 1 to explain in detail. Sections 4.1 through 4.4 present two computer labs: Time Series Data Patterns (#1 in Table 1) and Time Series Forecasting (#2 in Table 1) and two in-class activities: Overbooking a Flight using Decision Analysis (#5 in Table 1) and Overbooking a Flight using the Newsvendor Model (#7 in Table 1).

4.1. Time Series Data Patterns Computer Lab

This activity is done in small groups (2-3 students) in the computer lab and follows a mini-lecture on time series data and data patterns (stationary, trend, seasonality, and cycles). In this activity, students search the web to find time series data, load it into Excel (if not already in Excel format), plot it, and analyze the data to identify patterns. We provide students with a suggested list of websites as shown in Appendix A, but students may use other websites, if desired. The list that we give the students includes (1) US Census Bureau data on housing vacancies and homeownership, (2) Zillow data on median housing values and rents, (3) a variety of data sets on statcrunch.com, (4) US Government open data, and (5) data on NBA players.

We find it helpful if the instructor walks around to answer questions and check on students' progress. Many learning points arise when students are selecting data and analyzing the data for patterns, and we discuss some of these learning opportunities as follows.

- **Time series data.** Most likely at least one group will find an interesting data set that is not a time series, such as a list of shark attacks in statcrunch.com. The group will usually ask for help because they are not sure how to plot the data. Sometimes the data is transformable to a time series. For example, the list of the shark attacks could be summarized to report the number of shark attacks each year. Usually, though, students who do not have time series data end up finding other data. Other groups will download data that includes multiple time series. For example, the Zillow data may show housing or rent prices over time for each of the U.S. states. Students may not realize that they have 50 different time series and thus get confused as to what to plot and analyze.
- **Cyclical data.** Cycles are often found in the housing time series data (U.S. Census and Zillow websites) and can be difficult for students to identify. This provides an opportunity to discuss how housing prices tends to cycle with boom and bust periods like the housing bubble and collapse from 2006 to 2012.
- **Outliers.** Data from the Fox Sports website occasionally shows outliers. For example, the average points per game for an NBA player over his career may show one year with a very low average. When this happens, the students can research if anything unusual happened to the player that year, such as a debilitating injury.

The authors have found that students enjoy this exercise as they can pick data that they find interesting. The group and lab environment enables students to get help from other students or the instructor when they are stuck or have questions. Some of the learning points mentioned above can be summarized to the whole class at the end of class or at the beginning of the next class period. After completing the exercise, the students submit their data, a plot, and a short write up of their analysis.

4.2. Time Series Forecasting Computer Lab

This computer lab involves preparing forecasts using the time series data from the data patterns computer lab (described above in Section 4.1) and follows lectures on time series forecasting methods such as moving average, exponential smoothing, linear regression, and seasonal indices. Hence, there are usually two or three lectures between the two computer labs. Since this lab uses data from the earlier lab, the authors have found that it is wise to do a quick check of the students' time series data and analysis to address any issues with either before the start of this second part.

Using their data and analysis from the prior data patterns computer lab, students identify an appropriate forecasting method and use it to forecast the next period out from their time series. Depending on the time series, identifying an appropriate forecasting method may be straightforward or may require some judgment and assumptions. In the following, we discuss various data patterns and how to help students identify appropriate forecasting methods.

- **One data pattern throughout the time range.** Some data may have only one data pattern throughout the time series making it relatively easy to identify an appropriate method. For example, housing prices or rents over a relatively short period like two or three years may show a linear trend, making linear regression an obvious option.
- **Multiple data patterns throughout the time range.** Some of the housing data

over many years may show multiple data patterns such as trend and cycles. In this course, we do not cover methods for forecasting cycles, and we tell students that one school of thought is not to try to forecast cycles. In addition, we do not cover forecasting methods for both trend and seasonality, like decomposition or Winter's exponential smoothing. We tell students that methods exist for forecasting both trend and seasonality but are beyond the scope of the class. If a student group were to have data strongly exhibiting both trend and seasonality, it would be best for them to choose another time series to complete this computer lab.

- **Different data patterns in different time periods.** Some data may show different data patterns in different periods. For example, a time series of an NBA player's season average points per game over a long time like 10 years may show an initial trend up in the early part of the player's career and a trend down in the latter part of the player's career. In this case, it would make sense to use a downward trend to forecast for the next year.

After selecting a forecasting method and preparing a forecast for the next period out, students check that their forecasts make sense. This is important for two reasons: one is that it is easy to make mistakes in Excel, and second it is important to understand whether the forecast makes logical sense.

Even though this computer lab is not always straightforward for the students, most students appreciate working with real-world data, which can be messy at times. In addition, any interesting results from one particular group can be shared with the whole class.

4.3. Overbooking a Flight using Decision Analysis

This activity involves identifying the optimal number of seats to overbook for a flight using the expected monetary value (EMV) rule and follows a lecture on the EMV rule. To introduce this activity we discuss how airlines routinely overbook flights, as they know that some passengers will likely not show up for the flight. To maximize profits airlines must consider overbooking. If they do not overbook enough, then they lose opportunity for more revenue when there are empty seats. If they overbook too much, then they have to pay in travel vouchers to encourage passengers to give up their seats.

Students work in small groups and get flight information and prices for a couple of flights from our local airport (San Francisco). They choose one of the flights and then estimate how much they think the airline would have to pay in order to get a passenger to voluntarily give up his/her seat for a later flight. We discuss some of the factors that would affect this compensation amount. A major factor is how long a passenger would have to wait to take a later flight. One would expect that the longer the wait the more that the airline would have to offer. Hence, an airline would likely have to offer more compensation to get a volunteer to give up his/her seat on the last flight of the day to a particular destination than one for which additional flights occur that day.

We inform students that the airline is considering zero, one, or two overbookings and we provide students with a discrete probability distribution for the number of no shows. Appendix B shows the worksheet provided to students to calculate costs and expected values. We describe how to fill the worksheet out as follows.

Using the price per ticket for the flight, students fill out a table of the cost of empty seats for each overbooking/no show combination. For example, if there is one overbooking and two no shows, there is one empty seat at a cost equal to the price of the ticket. (We assume that the "no shows" are actually cancelling right before the flight and getting a refund.) If the number of overbookings is greater than or equal to the number of no shows, then no empty seats remain with no corresponding cost for empty seats.

Using their estimate of the compensation that an airline would have to pay to get a passenger to voluntarily give up his/her seat for a later flight, students fill out a table of the cost of travel vouchers for each overbooking/no show combination. For example, two overbookings and zero no shows results in two more passengers then seats, and the total cost of travel vouchers is twice the cost of one travel voucher. If the number of no shows is greater than or equal to the number of overbookings, then no travel vouchers need to be offered, resulting in this cost being zero.

Adding two types of costs in a table produces a total cost for each overbooking/no show combination. Students apply the EMV rule to this cost table and identify the overbooking option with the lowest expected cost.

4.4. Overbooking a Flight using the Newsvendor Model

Students consider the overbooking problem described previously following a lecture on the newsvendor model. Using the same data that they had when they solved the problem using the EMV rule, students calculate the shortage and excess costs and determine the optimal number of overbookings. The solution that they get from using the newsvendor model should match the result that they got from using the EMV rule.

Since the lecture on the newsvendor model is in the context of inventory, this problem is not straightforward for students to identify the shortage and excess costs. In the inventory setting, the shortage cost represents the cost of being one unit short in meeting demand, while the excess cost represents the cost of having one unit left over after demand occurs. In the overbooking problem, the shortage cost represents the cost of not overbooking enough and having an empty seat, while the excess cost represents the cost of overbooking too much and having to give out a travel voucher. One approach is to have students attempt to figure out the shortage and excess costs in this overbooking setting within their small groups. Another approach is to discuss it with the whole class at the beginning of the activity. We choose to do the latter. The former may be better in terms of learning, but the activity would take longer and require more help from the instructor.

Once the students have determined the shortage and excess costs, most are able to complete the calculations to find the optimal number of overbookings without much difficulty. One or two groups may find that their solution differs from the one they obtained with the EMV approach and end up needing help in identifying their mistake. Usually the problem is an incorrect shortage or excess cost.

At the end of the activity, students can share their results with the class, and we review how the groups with high values of travel voucher compensation (relative to the price of the ticket) obtain a low number of optimal overbookings (and vice versa). In addition, this is an opportunity to discuss how airlines can use data from actual flights in order to estimate the travel voucher compensation amount and the probability distribution of no shows.

V. STRATEGIES FOR SUCCESS

All co-authors had previously incorporated a few short hands-on-activities as part of their lectures, although not to the extent as in the newly designed experiential course. Based on our prior collective experience, we structured the lab-oriented class differently than a traditional lecture heavy class for successful implementation of a greater number of activities.

One of the key adjustments we had to make concerns class size. We reduced the class size from about 55 students to roughly 35 students. Since we do not have teaching assistants a class beyond 35-40 students would be unmanageable for reaching all students who need help with completing the activity in a timely manner. Given the wide range of students' pre-requisite knowledge, the time it takes for various groups to complete the activities can vary considerably. By limiting the class size, we indirectly limit the number of groups who need extra help not to fall behind.

Groups should consist of two to three students as we find that one or two students are often left out of discussions with groups of four or more. Small groups also enable shy students to join the discussion. Having computer-based activities poses an additional barrier on the group size because they take place in a computer lab where the students sit in a single row in front of the computers and have limited physical space to move around and form a circle. Therefore, it is not practical to have more than three students in a group in such a setting. This would be less of an issue at a university where most students bring their laptops to class. However, based on our observations, more than three students in a group is not effective for student learning and experience.

Creating activities that students can relate to from prior experiences is important. If the activity centers around a subject that seems foreign to many students, then students can feel lost. For example, one instructor tried a linear programming activity where students were to determine a diversified portfolio of investments using real data from Morningstar. The instructor found that students struggled with the activity because their experience with investing was limited. It was difficult for them to learn about linear programming while they were trying to learn about investment portfolios. On the other hand, overbooking of flights, which was used in two of the activities as described earlier, was something that students had either seen directly, or heard about on the news.

Having these activities be as realistic as possible also seem to be effective in engaging students. Students appreciate when they are working with more realistic problem settings, especially when the exercises incorporate real-world data. A few of the activities required students to search and choose for data online that fits their personal interests which raises engagement levels.

For the activities that have two parts (Forecasting #1 and #2, Project Management #8 and #9, and Quality Management #11 and #12), we find it useful to check the student's work from the first part of the activity prior to the students' starting the second part of the activity. By providing feedback to students on the first part, they can correct for mistakes before completing the second part. Since many of our students have limited experience with using mathematical approaches to solve real-world problems, we think the learning experience for our students is better with feedback and guidance than it would be without it.

Taking time at the end of an activity and discussing the results as a class is a valuable use of class time for a couple of reasons. Without this summary, students' knowledge acquisition may suffer depending on who was in their group and how much the instructor helped the group. Furthermore, student engagement increases when students' results or observations are discussed in a positive way in a group setting. Being positive is important; the instructor should not single out students in front of the class for doing something incorrectly.

As much as students enjoy these activities, it is important to provide students feedback and grade their in-class work for them to be fully motivated to complete them successfully. Otherwise, students may not see the point of the exercises and how they can improve their learning and subsequently their grade. All three instructors teaching this experiential version of the class had given a weight of 5%-20% to these activities when calculating final grades. This weight also has the added benefit of rewarding attendance; attendance is often low in our classes because most of our students commute to campus.

One final element is class sessions that are at least 75 minutes long. Ideally, once per week classes (2.5 hours) seem to work best for this format. One of the authors of this study had taught the class during the summer where students meet every day for 2 hours. In that case, implementation of the activities went very smoothly. During the fall term, that same instructor had 75-minute class sessions and noticed that students had a harder time completing the activities before class ended. Some groups fret about the time, negatively affecting their learning, and a few respondents cited insufficient time in the end of course survey. We believe some of the activities may need to be simplified to shorten the time it takes to do the activity or broken into smaller segments so that they can be completed across two 75-minute lectures.

VI. ASSESSMENT

Measuring the effectiveness of experiential teaching methods can be difficult as learning is unique to each individual, and it is difficult to come up with a reliable, simple proxy instrument. To address this issue, we use four assessment methods to evaluate the teaching effectiveness of the lab-based course.

- **Exams.** We compare exam performances when each of three instructors taught a lab-based section and a lecture-based section in the same semester.
- **Student surveys.** We summarize results from a survey given to students in the lab-based sections on how helpful each activity was in contributing to their learning of the material.
- **End-of-semester student evaluations of teaching effectiveness.** We compare end-of-semester evaluations for the lab-based section to that of the lecture section for each instructor.
- **Instructor observations.** We summarize the benefits and challenges of this the lab-based format class based on instructors' experience from teaching this course over three semesters.

6.1 Assessment of learning from exams

For assessment of learning purposes, students' performance in written exams were analyzed. In this class, the main learning goal for students is to be able to use relevant quantitative techniques and solve operations management problems. To analyze the impact of lab activities on student learning, in the 2017-2018 academic year, each of the three instructors taught two sections of this course simultaneously: one section lab-based and the other lecture-based. Each instructor gave the same exams to both the lab and lecture-based sections in the same semester, allowing assessment of the following three learning goals for the students:

- *Identification*: Recognize and justify the appropriate technique to apply.
- *Execution*: Execute the appropriate calculations competently.

- *Conclusion*: Interpret the result, considering whether it makes sense, and then communicate appropriate recommendations given the business context.

Exam questions were categorized by these three learning goals, which had been previously defined by departmental faculty for assessment of learning purposes. Accordingly, each student got a total of four scores: one for the overall exam and one for each of the three learning goals. In the remainder of the manuscript, the three learning goals are referred to as *Identification*, *Execution*, and *Conclusion*.

Two approaches were used to analyze students' scores and to determine whether or not the lab students (N = 130) performed better than the lecture students (N = 179). The first approach used the Chi-squared test for each learning goal to compare frequency counts for lab and lecture students in three competency categories, as detailed below. The second approach used ANOVA to compare standardized scores for lab and lecture students. As we shall see, both approaches came to the same conclusion. Student performance in all three learning goals were better for the lab students than the lecture students, and the differences in the identification and execution learning goals were statistically significant.

First, we discuss the approach that uses the Chi-squared test. In an approach similar to that of Coy et al. (2017), we counted the number of students in each of the three competency levels: *Fails to Meet Expectations, Meets Expectations, and Exceeds Expectations,* for each of the three learning objectives. Students who answered fewer than 70% of the questions correctly failed to meet expectations. Students who answered between 70% and 90% correctly met expectations. Students who answered at least 90% correctly exceeded expectations.

Table 3 provides the detailed assessment results. For each learning goal, the chi-square test results and percentage breakdown of students in a given class in terms of their competency levels are summarized. There is an apparent shift in the percentage of lab students from the *fail to meet expectations* and *meet expectations* categories to *exceed expectations* category in comparison to their counterparts in the lecture class. This shift is better captured in the column summarizing the percentage differences across the two versions of the class. These results show that for all three goals *fewer* students fail to meet expectations while *more* students exceed expectations in the lab class compared to the lecture class.

The Chi-square tests indicate that the observed differences between the two versions of the class were statistically significant in *Identification* and *Execution* with p-values of 0.006 and 0.007, respectively. However, the Chi-square test in *Conclusion* did not show statistical significance despite percentage differences being notable. Therefore, we conclude that the students attending the lab class are more likely than their lecture counterparts to perform very well (exceed expectations) in problem identification and execution and less likely than their lecture counterparts to fail to identify and execute the problems.

TABLE 3. ASSESSMENT RESULTS OF LEARNING GOALS

Learning Objective / Competency Level	*Identification*			*Execution*			*Conclusion*		
	Lab	Lecture	Difference (Lab-Lecture)	Lab	Lecture	Difference (Lab-Lecture)	Lab	Lecture	Difference (Lab-Lecture)
Fails to Meet Expectations	20%	30%	-10%	37%	47%	-10%	48%	55%	-7%
Meets Expectations	35%	43%	-8%	37%	41%	-4%	28%	29%	-1%
Exceeds Expectations	45%	27%	18%	26%	12%	14%	24%	16%	8%
Chi-square Significance (p-value)	0.006			0.007			0.223		

Next, we discuss the approach using ANOVA to compare standardized scores for lab and lecture students. For each learning goal and overall exam, each student's score was normalized using z-scores in order to have a standard scale across instructors. A z-score was calculated by taking the student's raw score, subtracting the mean score of all the students (lab and lecture) who took the same exam questions from the instructor in the given semester, then dividing by the standard deviation of the scores of all the students (lab and lecture) who took the same exam questions from that instructor in the given semester.

Table 4 summarizes the average z-scores for the lab and lecture students in the overall exam as well as those for the learning goals. Based on the overall exam z-scores, the students in the lab class on average performed better than those in the lecture class. Learning outcomes were also better on average for the lab students than the lecture students on all three learning goals with the highest difference in *Identification* followed by *Execution*.

To determine if these differences between teaching methods (lab vs. lecture) were significant or if there was any significant interaction between instructors and teaching method, we ran a two-factor ANOVA analysis for the overall exam scores and each of the three learning goals. The p-values associated with the teaching method (lab vs. lecture) for the overall exam and the learning goals are summarized in the same table as the average z-scores. The overall exam results show that the observed differences between the lecture and lab students were significant with a p-value of 0.002. The observed differences in the *Identification* and *Execution* learning goals between the two teaching methods were significant with p-values of less than 0.001 and 0.012, respectively, whereas for the *Conclusion* learning goal, they were not significant with a p-value of 0.103.

Furthermore, the ANOVA results imply that the impact of the lab teaching method did not depend on the instructor because there was no significant effect of the interaction between instructor and teaching method for the overall exam nor for any of the three learning goals. The four ANOVA tables are provided in Appendix C.

TABLE 4. SUMMARY RESULTS OF THE ANOVA ANALYSIS

	Lab students average z-score (N = 130)	Lecture students average z-score (N = 179)	Difference in average z-scores	ANOVA results: Lab/Lecture (Teaching Method) significance (p-value)
Overall	0.201	-0.147	0.348	0.002
Identification	0.242	-0.176	0.418	< 0.001
Execution	0.168	-0.122	0.290	0.012
Conclusion	0.109	-0.079	0.188	0.103

In summary, we have shown that lab students' performance was better than that of the lecture students in the overall exam and all three learning goals. While the lab students' performance in the *Conclusion* learning goal was better, on average, than that of the lecture students, the difference was not statistically significant. On the other hand, the differences were statistically significant in the *Identification* and *Execution* learning goals. This suggests that our lab approach is particularly helping students in identifying the proper method to use and executing the method correctly.

6.2 Student surveys

As this lab-based class is new, we endeavored to understand how the students perceive the helpfulness of the computer labs and activities adopted in the class. Appendix D presents the anonymous survey administered by the three instructors. The students were informed that the survey served only to collect their feedback about the activities they had done throughout the semester. Since each instructor covers slightly different activities, the activity list in the survey was modified to cover the actual activities in the corresponding class section.

The survey was distributed to the students during one Summer 2017 section and three Fall 2017 sections. One instructor surveyed the students twice: in the middle of the semester and at the end of the semester, while the other two instructors surveyed the students after all activities had been completed. We asked the students to indicate how strongly they felt each activity contributed to their understanding of the materials. For each activity, students who participated in it could indicate (via the four-level rating scale) the helpfulness of the activity (1 = not helpful, 2 = somewhat helpful, 3 = helpful, and 4 = very helpful). We also solicited free-form comments and suggestions regarding the lab-based format class at the end of the survey. The response rate for all sections ranged between 50% and 94%.

Table 5 summarizes the number of respondents in each rating score and the average score for each lab/activity. The average scores ranged from 3.4 to 3.7, with an overall average of 3.5 (out of 4.0). The results suggest that students found the activities quite helpful in their understanding of the course material.

In the free-form comment section of the survey, many students felt very positive about their experience in the lab-based class and found that the activities were enjoyable, engaging, and helped them understand the material. Many expressed that they preferred a lab-based class to a lecture-based class in the survey: "Activity based much preferred over lecture", "Activity based class time was much more entertaining. I was able to apply what I was learning to an actual activity which solidifies the subject," "I enjoyed the activities as they were there to enhance my learning and made calculations and tests easier. It prepared me and helped me understand the problems clearer. I prefer activity-based," "Really great activities, it helps tremendously with understanding the topic."

Students were positive about working in groups for the activities. Survey comments include: "I enjoy working in teams. Working together helps improve my learning," "Being involved with fellow classmates is easier and less stressful."

Some students also appreciated the fact that the activities broke up the lecture, especially for a long class such as a once-a-week class (2.5 hours) and summer class (2-4 hours), so they could stay focused. Students commented in the survey: "Enjoy! It breaks up lecture time and makes you think about real life situation(s)," "I prefer activity-based (class) to keep me awake," "In class activities are great for learning! Keeps me engaged and I'm practicing while learning."

A minority of students did not enjoy the activities as much as their peers did. For example, some students expressed that they still preferred more paper-based practice and lecture-based class due to the large amount of time taken by the activities, and some computer lab activities were challenging for them.

6.3 End-of-semester student evaluations of teaching effectiveness

So far, we have shown that the lab-based format creates a positive experience for students and results in better student performance in problem identification and methodology execution than the lecture-based format. In this section, we consider the impact of the lab-based class on student evaluations of teaching effectiveness. The on-line evaluation, conducted officially by the university at the end of the semester, consists of seven questions, and the students are asked to evaluate the instructor's teaching effectiveness for each question on a 5-point scale, from "strongly disagree/ineffective" to "strongly agree/highly effective".

In Fall 2017, we performed one-tailed t-tests to compare the end-of-semester student online evaluations of teaching effectiveness of the two classes (lab vs. lecture) for each instructor. A low p-value gives strong evidence that, for the given question, student satisfaction, on average, is higher in the lab-based class than the lecture-based class. Appendix E summarizes the one-tailed p-values for t-test comparisons of seven questions for the three instructors in Fall 2017.

TABLE 5. AVERAGE OF STUDENT RATINGS OF ACTIVITIES.

Topic Area	Activity	No. of respondents						Average score
		Not participate	Rating = 1	Rating = 2	Rating = 3	Rating = 4	Total	
Forecasting	1	0	3	3	29	51	86	3.5
	2	1	3	8	19	55	86	3.5
	3	0	0	2	17	24	43	3.5
Capacity Planning	4	2	0	4	11	52	69	3.7
	5	1	0	1	15.5	51.5	69	3.7
Inventory Management	6	0	0	2	10	15	27	3.5
	7	2	0	2	20	45	69	3.6
Project Management	8	2	1	8.5	28.5	41	81	3.4
	9	6	1	11	23	49	90	3.4
Linear Programming	10	3	0	8	30	65	106	3.6
Quality Management	11	1	0	5	16	25	47	3.4
	12	0	1	6	13	52	72	3.6
Overall Average score								3.5

Note: This is pooled survey results of four sections. The number of respondents (enrollment) are: 34(42), 31(33), 27(30) and 16(32), respectively. A few students chose both 2 and 3 or both 3 and 4 for some activities so 0.5 counts towards both ratings.

For the most part, the one-tailed p-values were statistically insignificant. We note that we would not necessarily expect to see statistical differences because of the nature of some of the questions. For example, we would not expect that the instructor defined information in the syllabus (Question 1) better for the lab class than the lecture class. Similarly, we would not anticipate students in the lab class to evaluate the instructor's timely feedback and openness (Questions 4 and 5) differently than their peers in the lecture-based class.

There were two results where the lab class average rating was significantly higher than that of the lecture class average rating. The p-value for Question 3 ("The instructor created experiences that stimulated my learning"), is significant for Instructor 3 (p-value = 0.018). We note that Instructor 3, taught the lab-based class in Fall 2017 with ten activities (see Table 2), which was the highest number of activities implemented in a semester. The p-value for the overall evaluation (Question 7) is significant for Instructor 2 (p-value = 0.005). We note that Instructor 2 taught both lab and lecture sections that met once per week in the late afternoon or evening for 2.5 hours. Perhaps the difference in overall satisfaction between Instructor 2's two sections can be explained by our observation that students often have a difficult time sitting through 2.5 hours of mostly lecture. The activities in the lab-based class broke up the lecture, making the class time in the lab-based class more satisfying than that of the lecture-based class. (We note that the other two Instructors' lecture-based sections were no more than 75 minutes.)

In summary, our results show that the lab format class format satisfies student expectations of teaching at least as well as the lecture-based class.

6.4 Instructor observations.

After teaching the lab-based class for three terms, we recognize both benefits and challenges to this new format. We first consider the benefits that we identified.

Hands-on learning experience. The in-class activities enable students to ask questions and get guidance when they need help. Consistent with the survey comments, students seemed engaged during the activities and they seemed to enjoy the activities.

Group work. As most activities used in the lab-based class occurred in groups, students got the chance to work with peers and learn from and help each other through discussion or even teach others within a group. In addition, one instructor observed that the group work created learning communities that continued outside of the in-class activities.

Class atmosphere. All three instructors observed that the lab-based class had a more positive atmosphere compared with the regular lecture class, and that the students tend to be more engaged in the lab-based class. We also noticed the lab-based class had better attendance, and the activities led to more active discussions and interactions among students and the instructors. Students often have a hard time sitting through lectures, and the activities broke up the lecture making the class time more appealing for students.

Skills improvement. We observed that students in the lab-based class became more proficient in Excel as the semester progressed. They showed more confidence working with Excel and learned new features every time they participated in the computer lab. (Note that in addition to the computer lab activities in Table 1, there were some sessions in the computer room where students learned how to use tools in Excel such as Solver and Regression Analysis.)

We also faced some challenges that need attention for future implementation.

Variation in skills. Students' wide variation in quantitative skills, especially Excel proficiency, poses a challenge for some computer lab activities. The instructors had to spend time helping students less adept with Excel. Some students struggled with basic spreadsheet functions before they could start doing the problems. Even though we reduced the class size, some students may still have not received adequate help as the instructor was assisting other students.

Time variation across groups. We find it often challenging to manage the time and progress of the activities as not all groups finish the activities concurrently. This can be partially attributed to students' different ability levels. In addition, some students take longer to make decisions than others. One way to address this issue would be to allow some time at the end of class for slower groups to finish the activity. Another approach could be to have groups finish the work outside of class.

Time management. Another drawback is the large amount of time taken by the activities because activities usually require more time than covering the material in a regular lecture. Thus, the lab-based class typically does not include optional topics (such as material requirements planning and waiting time analysis) or covers them at a reduced level. The group dynamics as mentioned above sometimes also caused time management issues for the already full curriculum of this core course. However, this can be compensated to some extent by a longer class time, such as teaching the lab-based class once a week in a 2.5-hour slot rather than twice a week with a 75-minute slot, so the instructor has more flexibility to adjust the pace of the class and activities.

VII. CONCLUSION

This paper outlines an experiential-based undergraduate operations management course developed and taught by the co-authors. The course offers a different learning experience than the traditional lecture style format through frequent computer labs and hands-on activities. Exam results imply that, on average, student performance is better with the lab-based class. More interestingly, when learning outcomes were analyzed, we found that students in the lab-based class were statistically significantly better at identifying the proper method and executing it but not statistically significantly better at reaching the correct conclusion.

Future research is needed to better understand why students' ability to interpret results does not necessarily improve through lab activities. One possibility is that being able to reach appropriate conclusions to the given business context requires a deeper understanding of the course material which may not be completely achieved with in-class lab activities. These activities, while engaging in nature and providing guidance to students in organizing their understanding of concepts with an experiential component, do not necessarily challenge a students' understanding at a deeper level given the time limitations of a class. One approach worth exploring is complementing these lab activities with homework assignments. These can be extended versions of the in-class activities that encourage students to analyze various scenarios and interpret the results of these scenarios.

In addition to the analysis of the students' performance and learning outcomes, we surveyed students' opinions. Survey results indicate that most students felt very positively about their experience in the lab-based class. The three professors teaching the course found the class atmosphere to be more positive with higher attendance and more classroom discussion in the lab-based classes than in the traditional lecture classes. Due to its success, we plan to continue to teach this lab-based course. We will continue to collect assessment data and continuously improve the course.

One area of future research is evaluating different lab activities to compare and contrast to see how the course helps improve critical thinking skills. Another area of future work involves exploring whether the lab-based format is better for particular learning styles as we may be able to direct students to the class format best suited to their learning style.

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Appendix A: Websites given to students for the time series data patterns activity.

US Census Bureau data on housing vacancies and homeownership:
http://www.census.gov/housing/hvs/data/histtabs.html
Zillow data on median housing values and rents:
http://www.zillow.com/research/data/
Wide variety of data sets:
http://www.statcrunch.com/5.0/shareddata.php?keywords=regression
US Government open data:
http://www.data.gov/
NBA players' data:
http://www.foxsports.com/nba/players

Appendix B: Overbooking a Flight using Decision Analysis

Cost of ticket = ___________________

Estimated cost of travel voucher for a bumped passenger = ___________________(How much $ do you think will need to be offered in order for someone to agree to take a later flight?)

Assume that the cost of an empty seat = the cost of the ticket.

The airline is trying to decide how many seats to overbook. They are considering zero, one, or two overbookings.

Cost of empty seats:

	No shows				
Decision	0	1	2	3	4
0 overbookings					
1 overbooking					
2 overbookings					

Cost of compensation (travel vouchers):

	No shows				
Decision	0	1	2	3	4
0 overbookings					
1 overbooking					
2 overbookings					

Total cost

	No shows				
Decision	0	1	2	3	4
0 overbookings					
1 overbooking					
2 overbookings					

From experience, they expect to have anywhere from zero to four no shows and they estimate the following probabilities:

No shows	0	1	2	3	4
	0.15	0.50	0.20	0.10	0.05

Decision	EMV
0 overbookings	
1 overbooking	
2 overbookings	

Optimal Decision = ______________________________. Expected cost = _____________.

Appendix C: ANOVA Results

ANOVA for Overall

	df	Sum of squares	Mean Square	F value	Pr(>F)	
Instructor	2	0.000	0.000	0.000	1.000	
Teaching Method	1	9.152	9.152	9.401	0.002	**
Instructor*Teaching Method	2	0.896	0.448	0.460	0.632	
Residuals	303	294.955	0.973			

ANOVA for *Identification*

	df	Sum of squares	Mean Square	F value	Pr(>F)	
Instructor	2	0.000	0.000	0.000	1.000	
Teaching Method	1	13.133	13.133	13.780	< 0.001	***
Instructor*Teaching Method	2	3.064	1.532	1.607	0.202	
Residuals	303	288.778	0.953			

ANOVA for *Execution*

	df	Sum of squares	Mean Square	F value	Pr(>F)	
Instructor	2	0.000	0.000	0.000	1.000	
Teaching Method	1	6.316	6.316	6.410	0.012	*
Instructor*Teaching Method	2	0.049	0.025	0.025	0.975	
Residuals	303	298.528	0.985			

ANOVA for Conclusion

	df	Sum of squares	Mean Square	F value	Pr(>F)
Instructor	2	0.000	0.000	0.000	1.000
Teaching Method	1	2.662	2.662	2.668	0.103
Instructor*Teaching Method	2	0.061	0.031	0.031	0.970
Residuals	303	302.393	0.998		

* significance at $\alpha = 0.05$
** significance at $\alpha = 0.01$
*** significance at $\alpha = 0.001$

Appendix D: Example of survey given to students midway through the semester

How well did each of the activities contribute to your understanding of the material:
N/A = did not participate. 1 = not helpful, 2 = somewhat helpful, 3 = helpful, 4 = very helpful

Forecasting: Data pattern activity (You got time series data and analyzed it for data patterns.)	N/A	1	2	3	4
Forecasting: Forecasting activity (You selected an appropriate forecasting method for your data and applied the method to your data.)	N/A	1	2	3	4
Capacity Planning: Breakeven activity (You selected a hotel and car for a trip to Hawaii and calculated the breakeven point for different capacity configurations.)	N/A	1	2	3	4
Capacity Planning: Overbooking activity: (You selected a flight and estimated the cost of a travel award, then calculated the cost for each combination of overbooking option and no shows. Then you calculated the EMV of each overbooking option.)	N/A	1	2	3	4
Inventory: Overbooking activity: (You applied the newsvendor model to the overbooking problem to find the optimal number of seats to overbook.)	N/A	1	2	3	4

Comments regarding the activities. Do you enjoy them? Do you not enjoy them? Which format do you prefer for this class: activity-based or lecture-based? Any suggestions or issues with the activity-based format?

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Appendix E: p-values from t-tests performed on end-of-semester student evaluations of teaching effectiveness

Evaluation question	Instructor 1	Instructor 2	Instructor 3
1. The instructor defined the course objectives, learning activities, requirements and grading policies clearly in the syllabus.	0.516	0.307	0.810
2. The course was organized in a way that helped my learning.	0.594	0.446	0.597
3. The instructor created experiences that stimulated my learning.	0.143	0.295	0.018
4. The instructor provided helpful and timely feedback on my performance and progress throughout the semester.	0.783	0.071	0.413
5. The instructor was open to a variety of points of view.	0.341	0.389	0.419
6. Please rate the overall effectiveness of your instructor on a scale ranging from the most positive response (highly effective) to the least positive response (ineffective). When I consider the contribution to my learning, this instructor's teaching was:	0.500	0.063	0.300
7. My overall evaluation of this instructor:	0.560	0.005	0.190
Sample sizes (lab vs. lecture)	30 vs 40	24 vs 35	27 vs 38