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Using Technology to Complete the Natural Learning Path in a Principles of Economics Course

Higher education is rapidly changing due to the convergence of two powerful trends: an improvement of our understanding of how students learn and the rise of online teaching technologies. Although there is general agreement that technologies are transforming education, there is less consensus on the optimal way to use these tools. This paper addresses this challenge by proposing a path of learning that focuses on two attributes of the learning process, time (when learning takes place) and space (where learning takes place). We show the application of our analysis by focusing on three critical components within the changing educational landscape: the role of the textbook, the role of the chalk-and-talk lecture, and the role of the physical classroom.

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1. Introduction

Higher education is rapidly changing due to the convergence of two powerful trends: an improvement of our understanding of how students learn and the surge of online technologies aimed at facilitating teaching. Although there is a general consensus that technology has made a transformative impact in higher education, there is much less agreement on the optimal implementation of these technological tools. For example, a cacophony of definitions and applications exists with the increasingly popular "flipped" and "online" classes. Another example is the common belief that, in order to implement active learning, one must remove the "chalk-and-talk" lecture from the learning path despite centuries of experience engaging students in this manner. The result is very little progress in answering key questions such as: what exactly do these methods entail, and how do faculty and administrators choose among the plethora of technological resources targeting these formats?

Much has been published on these basic questions. Yet, at least from the student's perspective, much of the analysis is fragmented—the study analyzes either the supply side by focusing on ways online technology might overcome the "cost disease," or the demand side by focusing on variables that determine student success. One reason for this separation is because the literature on educational issues is very interdisciplinary, creating challenges for researchers.

This paper aims to remedy this situation by proposing a framework that better integrates the analysis of these complex issues by focusing on the student learning path. This framework is useful for two important reasons. First, it explicitly focuses on two attributes of the learning process most affected by the use of technology: time (i.e., *when* learning takes place–the sequence of activities that students undertake before, during, and after class) and space (i.e., *where* learning takes place–in a physical classroom or in an online setting). And second, it offers enough simplicity for educators in any discipline to see the "big picture." Our goal is to show instructors how new technologies can complement existing learning models in a way that would allow one to more effectively navigate the vast online technology market.

2. The Evolution of the Student Learning Path in the Age of Online Technology

Over the past century, virtually all industries, including transportation, communications, health care, and agriculture, have been transformed with technological improvement, leading to a better standard of living. Education, however, has arguably been slower to transform, even with the exponential growth of online education and technologies. For example, many classrooms today still look very much like classrooms from a century ago, except for the addition of screens and projectors. Cowen and Tabarrok (2014) and Bowen (2012) alluded to the challenge of adapting to technologies by describing how online education will transform the industrial organizational structure of higher education over time. Much of their argument rests on whether online technologies allow higher education to overcome the so-called "cost disease." Yet, their focus was mostly on the supply side, those providing the instruction. We believe we can also learn about the process by focusing greater attention on the demand side, namely the students. One approach is to analyze the way online technologies have impacted student learning outcomes and the methods instructors use to achieve those outcomes. In other words, the student learning path is changing as new tools become available.

Prior to the widespread implementation of online learning, whether that be the introduction of entire courses taught online or the introduction of online learning systems aimed at complementing face-to-face classes, an optimal learning path generally posits that students prepare for lecture by reading texts, followed by attending lecture, then concluding with sum-

mative assessment exercises that are completed either with the use of course materials (homework) or by memory (quizzes and exams). As online technologies entered the marketplace, a divergence in paths has developed, with some instructors maintaining a traditional learning path while others implementing alternative paths that include popular techniques such as active learning, a flipped classroom, just-in-time (JIT) teaching, and team-based learning (TBL). An excellent compendium of pedagogical topics in economic education is provided by Hoyt and McGoldrick (2012). Couch, Harmon, and Alpert (2014) and Olitsky and Cosgrove (2016) provide valuable studies of the effectiveness of traditional versus flipped or active-learning formats.

Moreover, numerous studies have been published about the marginal effects (costs and benefits) of online versus face-to-face class formats (see Bettinger, Fox, Loeb & Taylor, 2017; Bosshardt and Chiang, 2016; Figlio, Rush, & Yin, 2013; and Means, Toyama, Murphy, Bakia, & Jones, 2010). Most studies to date find either no effect or an insignificant negative effect from online learning compared to face-to-face formats. But Bettinger et al. (2017) found longer-term consequences of online learning, such as lower grades in subsequent courses and a greater likelihood of withdrawals. Yet, these studies have typically treated online technologies as a substitute to face-to-face learning. In the present paper, we treat online technology as a complement to all classroom formats.

The divergence between studies that support and oppose online technology seems to be a function of the alluring effect any new technology creates for the consumer, in this case the instructor who adopts it, rather than any actual benefits within the student learning path. Therefore, despite many attempts at perfecting the use of available tools and their associated teaching methods, including various learning management systems, digital tools and resources, clicker and polling technologies, and pre-lecture and tutorial resources, little has changed with regards to connecting the stages within a student's learning path. For example, if a student reads a chapter or watches a video prior to class, the instructor then assumes the student is *better prepared* for class. But the classroom lecture itself might not change, other than perhaps being delivered at an accelerated pace. The missing link between student pre-class work and in-class learning lies in how instructors organize their lecture content *conditional* on student performance on pre-class work. In other words, a bridge is needed to connect pre-lecture activities with in-class activities. An important benefit of an effective learning path is to maximize the value of the work students do with their peers and with the instructor in the classroom. Deming, Goldin, Katz, and Yuchtman (2015) suggest that technology can reduce the cost of content delivery, but may not increase productivity. Analyzing the learning path with respect to technology would be a step forward.

The remainder of the paper focuses on deconstructing the student learning path and proposing new pathways that utilize technology in ways that were not easily implemented before, with emphasis on the time (when) and space (where) attributes of learning. We will use this analysis to evaluate the impact technology has had on three critical parts of the traditional student learning path: the textbook, the chalk-and-talk lecture, and the physical classroom.

3. The Role of the Textbook in the Natural Learning Path

In the traditional learning path, the textbook is designed to be used both at the beginning and at the end. A key assumption is that students read textbooks and gain adequate comprehension of concepts prior to class. Yet, anecdotal and empirical evidence suggest the opposite. Vazquez and Chiang (2015) analyzed large samples of students in principles-level courses in 2013 and found that only 29 percent of students completed required readings prior to class. Even when formative assessments were assigned as an incentive to read, students were more

inclined to answer the questions using *other* resources, often those found online. Therefore, students often skip this phase of the learning path and attend class without completing the readings.

The role of the textbook at the beginning of the learning path is less effective for two important reasons. First, when used as a source to complete corresponding assessment activities, the costs of searching in a textbook (either in analog or digital form) are considerably higher than alternatives such as Boolean searches using a web browser. In other words, searching the web provides a more familiar interface to students seeking answers than accessing content from a single book, resulting in a difference in search costs that do not favor textbooks. Second, text-based materials are not the optimal way to transfer new information to novices (Stelzer, Gladding, Mestre, & Brookes, 2009). Both dual coding theory and cognitive theory suggest that the brain processes and assimilates information in a manner that is more efficient when exposed to multiple sensory channels. Dual coding theory posits that conveying concepts in written form focuses on the brain's ability to understand and retain information via one channel (visual), whereas humans are better able to retain knowledge when presented via two channels (visual and verbal) (Paivio, 1986). Cognitive theory, however, suggests that short-term memory capacities (working memory) are very limited (Clark, Nguyen, & Sweller, 2005; Sweller, van Merrienboer, & Paas, 1998). When students use their working memory to connect words with stored images in their brain, there is less capacity for actual learning. Providing information using both visual and verbal channels eases the limits of one's working memory, thereby enhancing a student's ability to process and retain information.

The theories summarized above suggest that reading an entire textbook chapter prior to class tends to overwhelm the visual channel, resulting in less content being retained. One substantive change that has resulted is that many textbooks now contain more visuals (photos, infographics, etc.) than those in the past. Moreover, digital textbooks offer an opportunity to further expand the capabilities of the textbook beyond words, yet their development as a multi-sensory source is still in its infancy, especially among the most popular titles.

But there is still an essential role of textbooks in the learning path that cannot be overlooked; it simply lies toward the end once students have been exposed to content from multimedia sources and classroom interaction. At this later stage, search costs have fallen because students are familiar with the content. Textbooks that contain well-edited and curated content fulfill this part of the learning path effectively, which means textbooks are by no means obsolete. Instead, they serve as a valuable reference for post-lecture assessment and for advancing higher level knowledge in the subject.

4. The Role of the Chalk-and-Talk Lecture in the Natural Learning Path

The promotion of active learning as a teaching methodology over the last thirty years is a significant contribution from education research, both experimental and in the classroom. This has put enormous pressure on instructors to create time in the classroom to create and conduct active learning activities in place of the chalk-and-talk lecture. Some instructors create classroom time for active learning by simply removing the lecture altogether.

Yet, even the most rudimentary form of active learning requires the student to possess fundamental knowledge of the content in order to succeed. And if textbooks are not an effective tool to transfer this information to principles-level students, then another medium must be used to prepare students for active learning. Again, cognitive science research has addressed this issue: humans assimilate new information most efficiently with a multimedia presentation.

Paradoxically, the chalk-and-talk lecture is one of the best methods to fulfill this objective. The challenge then becomes time; there is simply not enough time in a classroom setting for lecture *and* active learning. As a result, the lecture becomes a bottleneck: if delivered in class, it limits time for active learning; if delivered online, the cost of creating and delivering lecture-quality multimedia content online has historically been prohibitive.

But over the past decade, the cost of producing multimedia lectures online has decreased due to technological innovations including lecture capture, better data compression, and cloud computing. Therefore, it is now possible to produce a chalk-and-talk lecture online that comes close to replacing the experience of seeing it in the classroom. Therefore, providing this component of the learning path has now become easier and more cost-effective[1].

The natural learning path involves the ability to move the chalk-and-talk lecture from within the classroom to the online setting to be completed *prior* to class. This multimedia tool would therefore replace the role of the textbook as the resource students use to familiarize themselves with concepts for the first time. Therefore, technology has allowed the separation between *time* and *space* from which students are introduced to a topic. The time may remain the same, but the lecture no longer takes place in the same space (classroom). When a multimedia presentation is used at the start of the learning path to prepare students for active learning, an important benefit of technological innovation becomes clear: students are able to achieve more with less effort because the path is more streamlined.

5. The Role of the Physical Classroom in the Natural Learning Path

In the traditional learning path, the classroom serves three functions: schedule synchronization, space synchronization, and scaffolding of the learning components. Schedule synchronization allows all students to receive certain instructional content at the same time, space synchronization allows all students to be at the same place, while scaffolding relates to the order by which students progress through the learning units.

And while each of these inputs enters into the learning production function of the classroom, this is primarily due to cost considerations and not necessarily productivity considerations. For example, when classroom time is used for chalk-and-talk lectures, schedule and space synchronization in this context means that all students receive content at the same time and in the same space. Scaffolding in this format means that students must wait until the class has concluded before proceeding to the next step of the learning path. Although there are clearly benefits to students from receiving content in the same physical place and time as others, these benefits would undoubtedly be very different in a course where class time is used for active learning exercises, such as team assignments or role play.

If the benefit of combining these inputs is not evident, then why do many classes still use chalk-and-talk instruction as opposed to individualized instruction? The answer is largely due to the costs of providing the multimedia presentation in a format tailored to individual students. An analogy would be a movie theater: once technology allowed movie watchers to view movies at their own time and place in a cost-effective manner, movie watching became more efficient, much like education has become more efficient with online lecture delivery mechanisms. Therefore, as the price of substitutes for classroom inputs fall, demand for classrooms

1 In fact, offering a recorded lecture to students before class is a component of what many call a flipped classroom. Vazquez and Chiang (2016) found using clinical trials that students whose first exposure to a new topic occurs via a video as opposed to a text achieve greater immediate comprehension as well as retention of concepts after a two-week period.

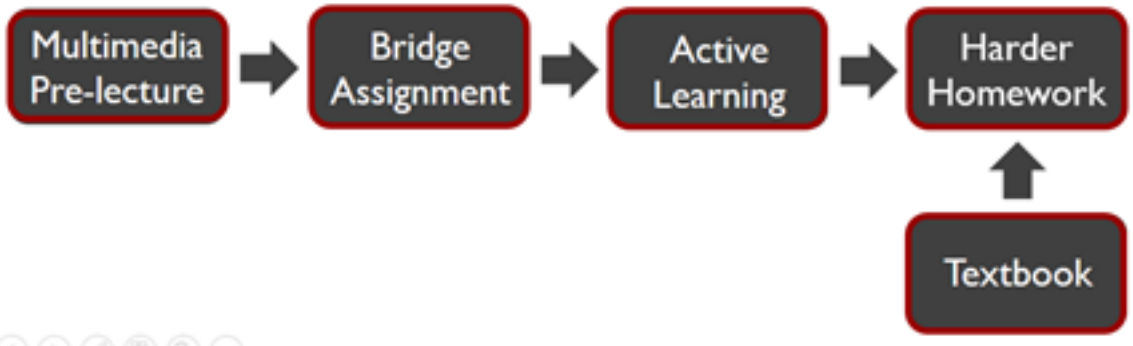
decreases as online solutions allow for scaffolding to occur in a more customized approach to each student.

Yet, the change in the price of classroom inputs have not fallen at the same pace. The cost of asynchronous learning activities (such as discussion boards) in an online environment is very low. For these activities in which synchronous interaction between students is not critical, the classroom input is relatively expensive. But the opposite is true for activities in which synchronous interaction is critical, such as active learning activities that depend on the value of student interaction within the same time and space.

Still, an evaluation of the three classroom inputs is necessary to measure the benefit of adding the physical classroom into the student learning path. The clearest example of not being able to delineate the differences among the three inputs can be seen in the research about the effects of online learning. Despite thousands of studies on this issue, only a handful use randomized trials or clearly define what constitutes the classroom variable. For example, Bowen, Chingos, Lack, & Nygren (2014) compares two modes of learning, with the treatment group using a hybrid format that includes one hour of face-to-face instruction per week to complement online content, while the control group received three to four hours of lecture without online content. Yet, without a clear description of what actually occurred in the face-to-face classes, it remains difficult to discern whether differences are due to an individual input (such as time or space) or some combination thereof. The important question therefore remains: when and for which course does space synchronization make a difference?

Returning to the restructured learning path, we can now summarize how online multimedia lectures can lead to a more effective utilization of the classroom by focusing on the increased efficiencies to improve learning goals. If students are better prepared for class, and class time is used more effectively to enhance learning, then students should be able to exhibit a higher level of understanding after class. One way to assess this outcome is to assign a more difficult homework after class. Figure 1 shows the restructured learning path using this approach.

Figure 1 – Restructured Student Learning Path



The restructured student-learning path begins with an introduction to the topic using a short online multimedia pre-lecture. Students then complete an activity (such as a formative assessment) that connects knowledge gained prior to class with activities to be pursued during class. Class time is then used for refining the knowledge using an active learning approach, which then leads to a more in-depth homework at the end of the learning path where the textbook becomes a valuable resource in achieving a higher level of knowledge. This learning path uses many advancements in educational technology developed over the past two decades and accomplishes the objectives in a cost effective way. The next section presents a sample class sequence implementing the restructured learning path using a common topic taught in introductory economics courses.

6. In Practice: The Topic of Elasticity of Demand Using the Restructured Learning Path

The pedagogical theories discussed in this paper lend itself to a multitude of implementation methods. In the following, we present one "best practice" using the restructured learning path, focusing on a topic covered in nearly all microeconomic principles classes: price elasticity of demand. Naturally, instructors can and should modify the details to best fit the characteristics of their students, class format, and their individual teaching style.

A. Part 1: Multimedia Pre-lecture

The first step for implementing the new learning path is to use technology to introduce fundamental concepts in an online setting (e.g., a pre-lecture) *prior* to the class meeting. The ideal pre-lecture is a short (10 to 15 minutes) recorded lecture that incorporates simple embedded questions to reinforce comprehension. The purpose of the pre-lecture is not to substitute for the full lecture, but rather to introduce key concepts so that students are familiar with the terms, allowing for a more seamless progression to more challenging details and applications during class. Moreover, when students are able to customize the pre-lecture (e.g., rewind and review) based on their understanding, this reduces the variance in students' knowledge of the topic prior to class, thus allowing class time to be used more effectively.

For the topic of elasticity, the pre-lecture would include the definition and a motivating example, the basic formula for calculating elasticity of demand, categorizing elasticity according to inelastic and elastic goods, and explaining the main determinants of elasticity. The embedded questions would reinforce these essential concepts without requiring any additional reading.

B. Part 2: Bridge Assignment

Tying the comprehension achieved through the pre-lecture to classroom activity requires the assignment of a few assessment questions following the pre-lecture that are more challenging than the embedded questions, but still rely mostly on the pre-lecture material. For example, a student might be asked to categorize elasticities based on the general slope (i.e., flat versus sleep) of a demand curve, or to determine the effect on a store's sales given an elasticity value and a price change. These questions require greater thought than mere regurgitation of concepts, yet still do not go beyond the scope of the fundamental material presented in the pre-lecture. Ideally, students would complete these exercises online with a due date being the day prior to class, thus allowing the instructor to review results and use class time to discuss common mistakes and misconceptions. Further, it allows instructors to determine which concepts show the greatest variance in student comprehension, which can then be emphasized in

an active-learning classroom to resolve common mistakes.

C. Part 3: Active-Learning Classroom

Once students have completed the pre-lecture and bridge questions prior to class, class time can subsequently be tailored for discussion, hands-on activities, and higher-order learning. But even if an instructor does not change anything (e.g., continues to use a traditional chalk-and-talk lecture), the benefits of the previous two activities are still effective in making class time more valuable, because students are not seeing concepts for the first time.

Moreover, class time is used to complement the pre-lecture by allowing instructors to progress more quickly to challenging concepts. For the topic of elasticity, these concepts would include the relationship between elasticity and total revenue, different methods of calculating percentage changes (e.g., the midpoint method), calculating elasticities from demand curves, and the introduction to other elasticities of demand (cross-elasticity and income elasticity).

D. Part 4: Post-Class Harder Homework

The final step of the new learning path is to reinforce the topic of elasticity through assignments that require a deeper understanding of the concepts. At this point, student comprehension has been aided by pre-lectures, bridge questions, and in-class active learning. The goal of the post-class homework is to challenge students to apply their knowledge to higher-order problems. It is also at this juncture in which the use of the textbook (as a reference) becomes most effective.

The main objective of the sequence is to be able to assign the most challenging questions on elasticity in a manner that does not result in a high percentage of incorrect answers. Anecdotal evidence suggests that when students are insufficiently prepared for class, learning and comprehension become less effective during class, and subsequently higher-order problems become more challenging. By progressing gradually toward more difficult concepts, improved learning outcomes are likely to be achieved.

7. Conclusion

This paper aims to combine research on cognitive science and economic education to shed light on the impact technology has had on three critical parts of the traditional student learning path: the textbook, the chalk-and-talk lecture, and the physical classroom. Our analysis is important not only because of the rare combination of these three dimensions into one cohesive analysis, but also because it focuses on the two variables most impacted by technology, time (when) and space (where), from the student's (demand for learning) point of view. Our analysis provides the following conclusions.

First, the role of the textbook within the student learning path should be reevaluated. Textbooks serve as valuable tools to reinforce concepts and to delve deeper into content to achieve a higher order understanding. Therefore, its place in the learning path carries a more prominent role toward the end of the path, and less so in the beginning.

Second, the role of the chalk-and-talk lecture is changing. The traditional use of the classroom for lecture was largely due to the cost efficiencies of delivering content to many students at once. Yet, as mechanisms for online lecture delivery improve and become less costly, the opportunity cost of using the classroom increases. Interestingly, this argument supports the use of chalk-and-talk lectures in the classroom when no alternative other than text-based materials

are feasible.

Last, the role of the physical classroom requires additional attention, because it requires a disaggregation of the three basic inputs of schedule and space synchronization and scaffolding. Further research should attempt to separate these effects in the learning production function, which requires clinical trial experiments focusing on specific chunks of the learning path instead of overall outcomes (such as exam or course grades). What is certain is that classrooms of the future will not look like classrooms of the past or present, as classrooms transform from spaces conducive to passive learning (lectures) to active learning (activities).

The student learning path is evolving due to technological innovations that affect the costs and benefits of delivering higher education. Nearly all class formats today incorporate online technologies to a certain extent, and the increased offerings of hybrid, lecture-capture, and other forms of online learning are becoming more commonplace. Yet, the learning path has been slow to evolve as technologies reform the classroom experience. This study presents a restructured learning path that aims to show how commonly available tools can be used to improve the sequence and flow of learning. There are many extensions to this analysis that remain unexplored. First, empirical studies, such as clinical trials, can be undertaken in a variety of classroom formats to compare the effectiveness of different learning paths. Second, additional emphasis needs to be placed on the implementation of the restructured learning path across the plethora of classroom formats. And finally, the analyses of both the costs (supply) and benefits (demand) need to be amalgamated in order to truly understand how technology affects what students learn and how they learn.

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