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Curriculum Complexity and Graduation Rates at Utah State University

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by

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Abstract

This study utilizes a curricular analytics framework developed by Heileman et al. (2018) to examine the relationship between curriculum complexity and graduation rates in academic programs at Utah State University. The goal in quantifying the complexity of curricula is to determine whether or not prerequisite courses and other factors of curricula structure impacts graduation from the university. To accomplish this goal, curriculum complexity spreadsheets were developed for 96 degree programs at the university, which facilitated the assignment of curriculum complexity scores to the 6,337 students who qualified for the quasi-experimental study. Logistic regression was then applied to the resulting data to plot graduation trends for students who graduated within four, five, and six years across the spectrum of curriculum complexity scores. The resulting trendlines indicate that increased curriculum complexity at Utah State University is significantly associated with lower graduation rates and calls for program administrators to restructure prerequisite structures to enable increased degree completion.

Dedication

For my wife Andrea.

Acknowledgements

I express my sincerest thanks to the Center for Student Analytics at Utah State University for supporting me throughout the preparation and analysis processes of this project. I would like to extend a special thank you to my mentor, Dr. Mitchell Colver, for his constant help and for answering even the silliest of my questions. I admire his leadership abilities and am grateful to have had the opportunity to associate with him throughout this project.

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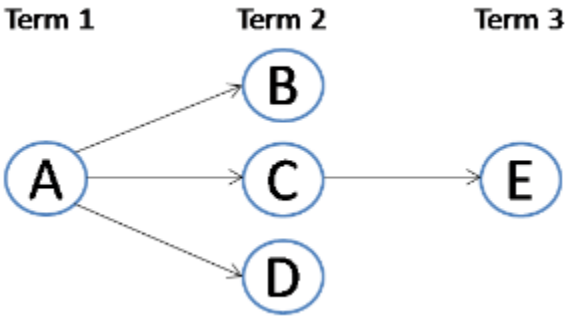
Introduction

Throughout history, in their endeavors to increase graduation rates and meet student success objectives, institutions of higher education have explored ways to facilitate student progression through academic curricula. Advising, on-campus housing, tutoring services, and Connections are all examples of co-curricular programs that Utah State University supports and has proven to be effective in helping students graduate (Center for Student Analytics, 2019; Hoopes, 2019). However, until recently, the effects of curriculum structure (i.e. the ordered combination of courses needed to complete an academic program) on student persistence to graduation had not been considered.

It would make sense that, independently of course difficulty and instructor factors, academic programs which require fewer prerequisite courses are easier to begin and complete than programs with many prerequisite courses. This would occur because prerequisite courses effectively block students from progressing in their program until completed. While many times essential to prepare students for upper-level courses, prerequisites often also restrict students' curriculum progression by offering them less scheduling flexibility and failure-tolerance, which in many cases causes them to delay graduation by one or more semesters and sometimes even drop out. A curriculum with less restrictive prerequisites and curriculum requirements, on the other hand, allows students to take their main classes earlier on, have more flexible class schedules, and retake classes without postponing graduation. Students in these programs can more easily navigate their academic program and are more empowered to control their education. As a result, they also tend to graduate at a higher rate than students enrolled in programs with more prerequisite courses, as evidenced below.

To compare the effects of prerequisites and other curriculum components on graduation rates between students in similar programs among several institutions, Ahmad (2016) proposed and Heileman et al. (2018) later developed a framework called curricular analytics. In this framework, each program is assigned a complexity score based on its structure that can be used to more easily identify the effect of curriculum structures on persistence towards graduation. The complexity score is derived from the cruciality of each course in the curriculum, which is in turn determined by the course's delay factor (the amount of time failing the course would postpone progression in the curriculum) and the course's blocking factor (the number of courses that a course is a prerequisite for) (Slim, Kozlick, Heileman, & Abdallah, 2014). The sum of these factors across all courses determines the complexity of the entire curriculum. Thus, programs with a higher curricular complexity score are more complex and more difficult for students to complete.

For example, consider the following curriculum:



The above graph depicts a program that at minimum would take three terms to be completed. As indicated by the arrows, course A is a prerequisite to courses B, C, and D, while course C is likewise a prerequisite to course E. In this way, course A is also a prerequisite to course E. The nature of this prerequisite structure is what determines the minimum number of terms to program completion, and is the focus of this analysis.

In order to determine the curricular complexity score of this program, each course's delay factor and blocking factor needs to be summed together. Delay factor, also known as longest path L_i, is the number of nodes on the longest prerequisite chain that includes the given course. In this case, the delay factor for courses A, C, and E would be 3, while the delay factor for B and D would be 2. Blocking factor V_i, on the other hand, is the number of courses that can only be taken after the given course is taken. Thus, the blocking factor for A would be 4 and the blocking factor for C would be 1. Course cruciality, as defined by Slim et al., is the sum of the delay and blocking factors (Slim, Kozlick, Heileman, & Abdallah, 2014). Curricular complexity can be calculated by adding together the course cruciality of all the courses. Thus, the curricular complexity of the above curriculum can be calculated as follows:

Course	L_i	V_i	C_i
A	3	4	7
B	3	1	4
C	3	0	3
D	3	1	4
E	3	0	3
Curriculum Complexity Score			21

This relationship between prerequisites and the ability for students to progress through their academic program to graduation is thus reduced to a single value called curriculum complexity score. In this study, degree programs at Utah State University were examined using the curricular complexity framework and assigned a curriculum complexity score. Graduation rates were then explored among the different programs using curriculum complexity score and four-, five-, and six-year graduation rates.

One common criticism of the curricular analytics framework argues that the increased blocking that occurs in high complexity programs might not necessarily be due to prerequisite structures, but rather that it is an unavoidable byproduct of rigorous, high-quality programs. However, Heileman et al. disproved this theory by comparing 62 electrical engineering programs from high-, mid-, and low-tier universities by perceived quality and curriculum complexity score (2019). In essence, the study proved that higher quality programs boast significantly lower complexity scores while the lower quality programs use higher complexity scores. Weilend et al. echoes this claim as well, stating that the most "highly regarding programs often [have] the most efficient curricula" (Wigdahl, 2014). The study also considered that higher quality institutions may tend to ingress higher-achieving students and can thus prepare them sufficiently for post-academia careers without the need for many prerequisites. To this, Heileman et al. responds that many high-tier universities showed progressive decreases in curricular complexity by restructuring their program curricula, especially during the first year of study (2019). This implies that program quality cannot necessarily be measured by curricular complexity.

Understanding the relationship between curricular complexity and graduation rates at Utah State University is an essential step for increasing students' abilities to complete academic programs. If a negative relationship is found to exist between curricular complexity and four-, five-, and six-year graduation rates, it can be stated with confidence that degree programs at Utah State University follow the pattern hypothesized by Heileman et al. and implies the need to revise their structure. On the contrary, if the relationship between curricular complexity and graduation rates is insignificant, there is no evidence that rearranging program curricula will affect student graduation rates.

Methods

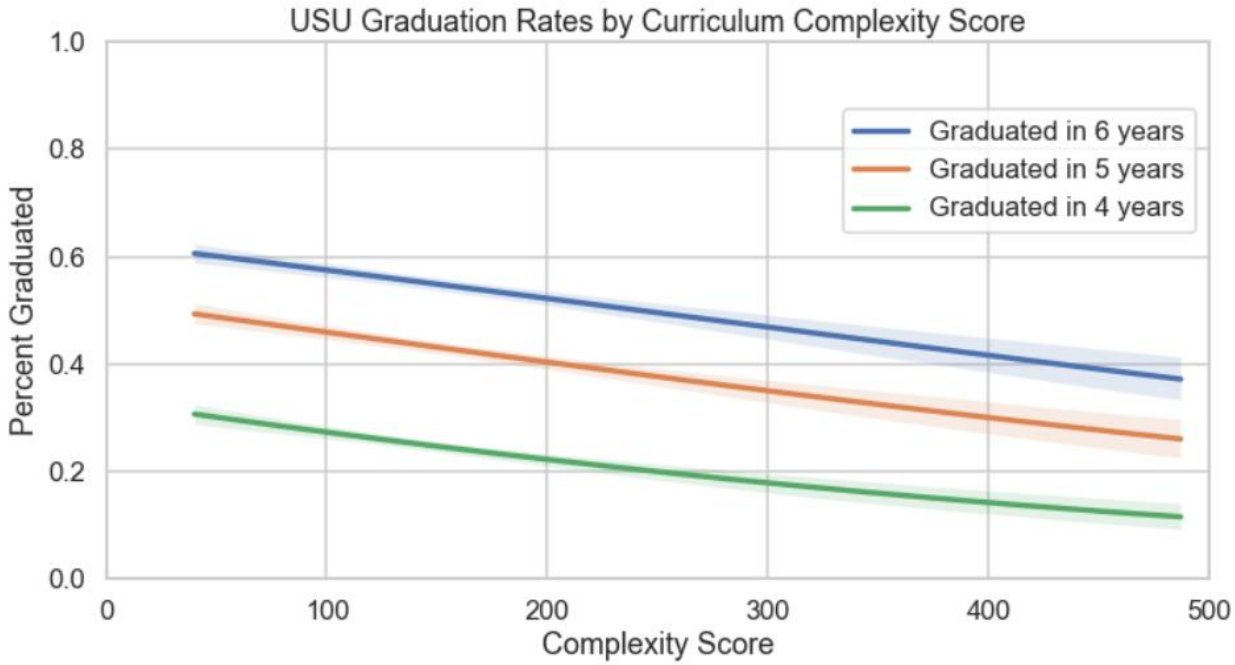
Heileman's curricular analytics model was applied to 96 academic programs at Utah State University. First, degree maps for 4-year undergraduate programs were translated from the university catalog to individual comma-separated values files and then uploaded to the comprehensive curriculum analytics repository at www.curricularanalytics.org. The repository then executed a computation on each curriculum and assigned each program a curriculum complexity score using the methodology defined above (Heileman et al. 2018). Program scores ranged from 40 to 487, with higher scores indicating higher complexity programs.

Graduation data were taken from first-time college students enrolled in a degree-seeking program during a fall semester between 2012 and 2015. These students represent traditional degree-seekers who were part of one of the 96 academic programs examined through the curricular complexity model and constitute a representative sample of the population at Utah State University. In total, 6,337 students were available for the analysis.

Each student was assigned a 1 or a 0 to indicate whether they graduated in 4, 5, or 6 years. Logistic regression was then used to visualize the general trend between curriculum complexity score and graduation in 4, 5, and 6 years. The trendlines generated by this algorithm were the primary interest of this study and were used to obtain a general idea regarding the relationship between curricular complexity and graduation rates.

Results

The analysis revealed that curricular complexity shares a negative relationship with four-, five-, and six-year graduation rates at Utah State University. Each trendline for students who graduated within these time frames was based on a coefficient of roughly 0.0005, meaning that for each additional point in a program's curriculum complexity score, graduation rates decreased by 0.05%.



In this graph, students were plotted as points either on the top of the graph (if they graduated) or the bottom of the graph (if they did not graduate). They were oriented horizontally by their complexity score (x-axis) and trend lines were plotted against the percentage of students who either graduated or not (y-axis). The points were later removed to improve visual clarity.

Discussion

The above analysis, in synthesis with the theories proposed by Heileman et al. (2018), produced a clear snapshot of the effects of high curricular complexity and graduation rates in academic programs at Utah State University. Throughout the study, three prominent themes developed:

As curricular complexity goes up, graduation rates go down.

As evidenced in the graph, as a general trend, students enrolled in academic programs with higher curriculum complexity scores graduate at lower rates than students enrolled in programs with lower curriculum complexity scores. In contrast, students enrolled in programs with lower curriculum complexity scores graduated at a slightly higher rate. Interestingly, this pattern occurs

relatively evenly across groups of students who graduated within 4, 5, and 6 years. This confirms that curriculum complexity score significantly influences graduation rates at Utah State University.

Prerequisite courses cause increased curricular complexity.

The cause of higher complexity scores is prerequisite courses. While oftentimes necessary for building a foundational knowledge, prerequisites also serve to block students from progressing towards graduation. When degree programs have long prerequisite chains that defer access to higher level courses, students have less flexibility in their schedules and many times are forced to postpone graduation if any changes to the plan are made. This would include a change of major, failure of a course, or transferring from another university. Program administrators know that less flexibility is a problem for students, but they must also ensure that each program provides sufficient foundation knowledge to students to help them excel later in their studies and in their careers. Thus, program administrators face the difficult task of determining how to both reduce curricular complexity and maintain high standards of attainment for their students.

Re-evaluating prerequisite courses can lead to decreased curricular complexity and, therefore, higher graduation rates.

Fortunately, programs don't need to get rid of prerequisites to decrease their complexity, but instead need to be simply **reorganized**. As noted by Heileman et al., two engineering programs with identical accreditation will experience vastly different graduation rates, even though both programs teach the same courses (2018). The difference between them lies in their curriculum structure, where the less complex program (with more graduations) combines, eliminates, or rearranges prerequisites to allow the program to be more forgiving and easier to manage for students. Likewise, program administrators at Utah State University should re-evaluate their programs to see where choke points and prerequisite requirements seem to impede student progression. As they do this, administrators will find ways to reorganize the prerequisites in a way that is failure-tolerant and flexible, and that allows students to graduate from the program at a higher rate while still providing them with the foundational knowledge they will need in their careers.

Reflection

Completion of this Honors Capstone is the result of a very long journey. I was first introduced to curricular analytics as a newly hired Undergraduate Researcher at the Center for Student Analytics, where Dr. Mitchell Colver was essentially pioneering the use of Dr. Heileman's curricular analytics framework (described above) for the first time outside of the founder's native Arizona. I didn't have any clue what the implications of the research were, but was instructed simply to turn curricula from the Utah State University website into formatted spreadsheets. I was then instructed to run the spreadsheets through Dr. Heileman's formula on the website www.curricularanalytics.org and record the curriculum complexity score on another spreadsheet.

Two years later, I became the person instructing others on how to turn example curricula from the university catalog into spreadsheets. I made tutorial videos, set up several Zoom calls, and answered countless questions from my assistants who helped me translate the programs to specially formatted spreadsheets. Because my mentor was, at that point, no longer working at the Center for Student Analytics, I was forced to become the most knowledgeable person at the university regarding curricular analytics… and I enjoyed it.

Today, curricular analytics is a very important topic to university administrators. As one of the few researchers studying the topic, my project was specifically created using non-academic language and semi-detailed explanations to make curricular analytics more accessible to non-technical stakeholders who can nudge program creators and instigate change in their degree structures. My goal was to provide convincing evidence that program structure and graduation rates share a significant relationship that could warrant additional study. The results of this study were thus intended not to show that program restructuring works at Utah State University, but that restructuring could likely create a positive impact on student graduation rates.

Throughout this project, I learned that I love technical writing. While I have always seemed to have a "knack" for writing, I discovered after creating this report that I enjoy being able to summarize concepts concisely, especially when they are directed at a less technical audience. In this project, for example, the details of the curricular analytics calculation are very important, and I addressed them sufficiently in the introduction. However, I didn't go into great detail in such a way that could have taken me several pages of dry text and which would have catered to a more academic audience. Because my project needs to appeal to a more general public, I needed to find a balance in the depth of my explanations.

My relationship with Dr. Colver was also fundamental to my personal growth as a leader. Dr. Colver is a leader by example, and I find his strong opinions regarding the importance of analytics in higher education both refreshing and enlightening. He constantly asks for feedback and is very focused on enabling others to perform at their highest level. In this project, Dr. Colver frequently answered my questions with other questions, a response that was often frustrating to me but which ended up helping me learn how to solve problems by myself. From his example, I have learned to be inviting of feedback from others and critical of the data.

The project deepened my knowledge of information systems by exposing me to the entire data analytics lifecycle. In the project, I collected, compiled, analyzed, and presented information using the data all in a single project. The collection part was by far the lengthiest part of the entire project, taking up around 60% of the total time spent. This was incredibly frustrating because it deferred the completion time somewhat, but also made me appreciate having a structure in place that could automate the data collection process. In future analyses of curricular analytics, I might attempt to create an automated process that performs the data collection for me that can be used as new degree programs are added to the university catalog and others are updated.

More than anything, working with curricular analytics has exposed me quite a bit to education theory. Before starting on this project, I had never considered that the literature surrounding

education theory in general could be so large. Now, however, I find that my research fits into a niche category that meets a very specific need that has not been solved yet. I've grown from the world of information technology into education and found a place where all of my interdisciplinary skills are needed.

Overall, completing a capstone project has been a tough, but worthwhile, experience. It gave me a safe way to complete innovative research under the guidance of a talented mentor, and has helped me to learn about my own skills in both writing and analytics. With luck, my research will reach university administration and serve as a tool for improving degree programs across the institution, thus streamlining degree attainment for future students.

Bio

Hayden Hoopes is originally from Weiser, Idaho and is studying Management Information Systems and Spanish with a minor in Music. In addition to his participation in the Honors Program, Hayden was also a cohort leader in the Huntsman Scholar Program and recipient of the Data Ninja scholarship award. Hayden has worked as an Undergraduate Researcher at Utah State University and also as an instructor in the Data Analytics department at Bridgerland Technical College. He currently plans to pursue a Master's of Data Analytics at Utah State University.

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