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Examining the Replication – or Mutation – Processes of Implementing a National Model for Engineering Mathematics Education at a New Site

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engineering design backgrounds. Derek is also an award-winning teacher and was most recently awarded the John and Mercedes Peebles Innovation in Education from CU's College of Engineering and Applied Science. Dr. Reamon received his PhD in engineering education from Stanford University in 1999. His dissertation was one the first in the nascent field of engineering education research.

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Ken Anderson is a Professor of Computer Science and the Associate Dean for Education for the College of Engineering and Applied Science at the University of Colorado Boulder. He co-directs Project EPIC, an NSF-funded project since 2009 that investigates how members of the public make use of social media during times of mass emergency. Professor Anderson leads the design and implementation of a large-scale data collection and analysis system for that project.

Prof. Anderson was a participant in the first cohort of the NCWIT Pacesetters program, a program designed to recruit more women to the field of computer science and encourage them to pursue their careers in technology.

As part of his Pacesetters efforts, Prof. Anderson led the charge to create a new BA in CS degree at CU that allows students in Arts and Sciences to earn a degree in computer science. This new degree program was first offered in Fall 2013 and had 240 students enroll during its first semester and now has more than 900 majors four years later.

He also organizes and hosts the annual NCWIT Colorado Aspirations in Computing Award for the past eight years. This award recognizes the computing achievements of female high school students in Colorado and encourages them to enroll in computer science at the college level. Since 2010, over 400 young women in computing have been recognized by these events.

Prof. Anderson received his Ph.D. in Computer Science in 1997 at the University of California, Irvine. His research interests include hypermedia, the design of reliable large-scale software infrastructure, the design and implementation of data-intensive systems, and the design of web application frameworks.

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Keywords: ethnography, transformation, intervention, engineering mathematics, curricular change, translation, networks, models, replication, mutation, Wright State Model

Abstract

This research paper investigates how a renowned national model for engineering mathematics education is adapted and adjusted for implementation within a new large public university site, and the consequences of these modifications for students, instructors, administrators, and institutions. By examining how elements of the original Wright State Model are replicated or *mutated* in the process of starting a pilot course, we illustrate not just the challenges inherent to creating a new course in a new place but also the ways seemingly neutral and benign objects (such as course numbers and course titles) are transformed and modified to suit local contexts. Further, we show what is lost and gained through the adaptation and conversion processes of moving an established course model from one institution to another. We argue that these negotiations and local compromises are worthy of detailed examination to understand more about the existing social organization of academic institutions in order to reveal structures that both limit and enable the success or failure of educational initiatives and innovations. This paper integrates ethnographic data, institutional artifacts, and student survey responses to demonstrate how the pilot course implementation is not a one-to-one replication of the original model; rather it is a *mutation* of how the course exists at Wright State. Viewing the course as a *mutation* enables a deeper analysis of the institutional processes required to instantiate a new educational initiative within existing systems, curricula, and infrastructures, with implications for engineering educators looking to make positive change within their home institutions.

Introduction

This research paper examines how change is effected within durable systems. The context for the study is the process of incorporating a proven educational intervention into the rigid network of an undergraduate engineering math prerequisite sequence at a large public research university. Various researchers have pointed to Wright State's *Introductory Mathematics for Engineering Applications* course as a model for undergraduate engineering education curricular reform (Klingbeil, Mercer, Rattan, Raymer, & Reynolds, 2006). This paper shows how, as attributes of the original successful model become adapted to local necessities and constraints, seemingly neutral and benign objects (such as course numbers and course titles) are transformed and modified within local contexts. Further, we show what is lost and gained through the adaptation and conversion processes. We also explore the consequences, some unintended, of this adjustment process. We argue that the challenge of implementing something new is not just an issue of institutional support and funding, but rather a process of *translation* that has implications for the identities of people and institutions involved (Latour, 1987; Tsai, 2015).

In following the *Engineering Math* course as it moves from its original context to a new setting, we pay particular note to how it is translated: which course aspects are modified and which are preserved, how academic negotiations are conducted, and how curricular decisions are made. We assert that this careful attention to the process and the organization of *how* decisions are made and *who* is making them is necessary to prevent the course from "acquiring inertia" and consequently the intentions and reasoning of course designers becoming invisible (Bowker & Star, 1999, p. 324–325). This paper is one means of maintaining visibility of the actions and actors involved in implementing an instantiation of the *Introductory Mathematics for Engineering Applications* course at a Large Public University (LPU) in order to maintain awareness of the boundaries being drawn as the course is created within existing schemes of classification and other infrastructures. In turn, this enables researchers and course designers to see who and what is being left out during these decisions, and what is left behind as this course model traverses from one location in time and space to another.

Background: Replication vs. Mutation of the Wright State Model for Engineering Mathematics Education

The Wright State Model (WSM) is a semester-long math course that teaches fundamental concepts of *Calculus 1, 2, 3*, and *Differential Equations* in an engineering context through hands-on laboratory experiences and application-rich problems. The WSM is designed to disrupt the traditional rigid sequencing of undergraduate engineering curricula by decoupling mathematics prerequisites from engineering coursework—introducing undergraduates to sufficient mathematical tools in the one-semester course to enable them to get started and make progress in technical engineering coursework, regardless of their parallel progression through the traditional mandatory mathematics sequence. The WSM does not replace any mathematics courses along the undergraduate engineering degree pathway; rather it provides engineering students with a strong foundation and justification for learning mathematics, rooted in the utility of math as a tool for engineers (Klingbeil et al., 2006).

The course designers suggest that the WSM "is designed to be readily adopted by any institution employing a traditional engineering curriculum…" (Klingbeil & Bourne, 2013, p. 10). With a track record of successful replication across a broad spectrum of American engineering and technology schools—including large public engineering colleges, private high school preparatory programs, and community colleges (Klingbeil et al., 2008; Klingbeil, Newberry, Donaldson, & Ozdogan, 2010; Long, Abrams, Barclay, & Paulson, 2016)—clear evidence exists to support the claim that the WSM can be readily integrated into an institution's curricula. For the last nine years, Wright State has hosted annual meetings with more than 17 collaborating institutions to facilitate in-person discussions and comparisons of local WSM implementations (National Engineering Mathematics Consortium, 2018). Furthermore, a published textbook of the WSM curriculum, as well as a free online web portal featuring lecture videos, lab demonstrations, and other references serve as accessible and mobile resources for instructors and administrators to employ in WSM courses at their own institutions (Rattan & Klingbeil, 2014; The Wright State Model for Engineering Mathematics Education, 2017).

The textbook and readily available online resources maintain coherence between the original and new WSM course implementations by providing content and structure for the academic activities. Given these resources, replicating the course and duplicating its outcomes related to increasing persistence and retention of engineering undergraduates might appear to present few challenges. Yet, launching an implementation within a new context requires negotiation and trade-offs not discussed in the prior literature.

As we discovered, many course aspects were not easily transported from the original context into a new one without significant adjustment and change. Rather than direct replication of aspects of the WSM, we notice that many course attributes were modified and altered—mutated rather than duplicated—in order to fit into a new academic setting. We argue that these negotiations and local compromises must be further examined to understand more about the existing social organization of academic institutions, to reveal structures that both limit and enable the success or failure of educational initiatives and innovations exemplified by the WSM.

Our analysis considers the many elements—geography, time, people, politics, places, artifacts (curricular flowcharts, grading systems, online learning management platforms), recordkeeping and gatekeeping systems—that must be modified, cajoled, adjusted, altered, adapted, so that a "fit" can be made for the course in an entirely new context. In other words, we reveal the active and dynamic process of *translation* at work in order to move an educational intervention from one setting and educational system into an existing *actor-network* of undergraduate engineering education at a large public university.

Theoretical Framework: Situated Actor-Networks and Course Translations

To further contextualize our analysis of the course implementation process presented in this paper, we start by defining our theoretical stance. We are inspired by Johri & Olds (2011) and the learning sciences field—advocates of *situativity* and *situated frameworks* to re-conceptualize engineering education and engineering education research. As they explain, "a central aim of the situated perspective is to understand learning as situated in a complex web of social organization rather than as a shift in mental structures of a learner" (2011, p. 160). To study learning as it occurs in the WSM, we first seek to understand and map these "complex webs" of social terrain to explore how different organizing conditions of these webs—or networks—differentially influence student learning.

We are further informed by engineering education researchers who have demonstrated the usefulness of this approach for revealing insights into the many ways students are shaped by the institutional structures and narratives common to undergraduate engineering programs, with consequences for students' engineering identity development and acquisition of engineering knowledge (Stevens, O'Connor, Garrison, Jocuns, & Amos, 2008). This paper builds on the tradition and follows the mandate: "Research on learning must centrally involve attention to *processes of the organizing of processes* through which people move along trajectories into their futures, including the conditions in which people become recognized, or not, as valued participants in social worlds" (Johri, Olds, & O'Connor, 2014, p. 61, emphasis added). Indeed, we attune our analysis to identifying the organizing processes at multiple levels that structure the lived experiences and shape the identities of our students (Penuel & O'Connor, 2010).

These organizing processes encompass all administrative, coordination, and instructional tasks, decisions, and negotiations implicated in starting a new educational initiative such as the WSM at the LPU under study. We utilize actor-network theory and specifically *translation* as a framework to categorize the various actions and events observed during the process of creating the WSM within the LPU in order to aid in mapping the terrain of this initiative as it begins to take root in new soil (Callon, 1986; Latour, 1987; Tsai, Kotys-Schwartz, & Knight, 2015). For example, in actor-network language, the textbook and online resources are examples of *inscriptions:* data or information officially recorded in an immutable form for portability and transfer from one location or another, easily replicated and reproducible for dissemination across time and space (Johri & Olds, 2011; Latour, 1987). We examine how these *inscriptions* travel from Wright State to the LPU, and note if they remain unchanged after the journey and what other course-related items are modified or altered in transit. Charting the activities involved in course initiation reveals the prevailing organizing conditions of processes within the LPU with consequences for the ways we design our courses and curricular pathways for students to move through degree programs. Additionally, "following the actors" and pinpointing the actions required to enable educational innovations to survive and propagate has distinct practical implications for anyone wishing to affect change within engineering education (Latour, 1987).

To understand how the WSM is replicated and adapted for LPU implementation, we focus on the central organizing process of actor-network theory, *translation*. Translation describes how an actor, human or non-human, is recruited into joining the movements of an *actor-network*, where an actor-network is an assemblage of actors implicated together by association and activity (Callon, 1986; Nespor, 1994). In this study, we examine the ways the WSM (an actor unto itself) is modified as it is gradually absorbed or *translated* into the existing *actor-networks* of the LPU. Translation is classically defined as having four *moments* or overlapping stages: *problematization, interessement, enrollment, and mobilization.* As we delineate in the Findings, these *four moments of translation* are a useful classification scheme for analyzing the process wherein an actor like the WSM is able to join and move through a new *actor-network*. Throughout, we focus on understanding what it means to start something in a new context, not just as a process of "making academic change happen," but as a gradual transformation of social organization and order (Rose-Hulman Institute of Technology, 2017).

Methods

This paper presents an ethnographic, narrative analysis of the process of proposing the pilot course, getting it into the course catalog, then following it through the pilot implementation semester. The ethnographic data cover a period of about one calendar year, beginning in spring 2017, continuing through summer planning months and through the first course offering during the fall 2017 semester. This analysis is timely as the events have recently occurred and the details of each negotiation and adaptation are not yet obscured by the broad brush strokes of institutional record.

The bulk of data shared in this paper include auto-ethnographic observations and recollections based on the lived experiences of the course instructor and coordinator, the assessment director, and supporting administrators and researchers (Ellis, Adams, & Bochner, 2011). Institutional artifacts constitute a secondary source of data; they include presentation slides, emails and other written communications, curricular flowcharts and other digital files that illustrate the historical record of events and organizing processes wherein the WSM is *translated* into a pilot course. A third source of data are survey responses from students who dropped the course prior to its start. Survey responses were incentivized with a $10 gift card to an LPU coffee shop. Students responded to a simple two-question survey that asked 1) What factors did you consider in your decision to drop the course? and 2) How did information from your advisor inform your choice? Eight students were eligible, of which six responded to the survey (75% response rate).

This paper integrates ethnographic data, institutional artifacts, and survey responses from students who dropped the course to address the following **research questions**:

1. What are the consequences—for students, instructors, administration and the course itself—of modifying aspects of the original course model, through active processes of adaptation and translation, to fit the needs and demands of new contexts?

2. What is revealed about an institution and its processes of organizing when we closely examine what is required to replicate or mutate a successful national educational model within a local context?

3. What can engineering educators learn from this story of change to make impactful decisions for their own contexts, to prioritize certain transformations over others and enable smoother integration of new curricula into long-standing traditions and institutional structures?

Data Analysis Process

The basic narrative describing the full process wherein the course was initially proposed, modified to fit within the LPU, then piloted, was first documented as an analytic memo by the first author with a focus on capturing the basic events, main actors and their key actions. This memo was circulated among the co-authors and external engineering education researchers for comments and discussion, leading to the theoretical analysis of the events as a process of *translation* and interpretation of the narrative record in line with *situativity* and actor-network theory. As this analysis deepened and grew more sophisticated, the narrative analysis of events also became more detailed by adding supporting data in the form of institutional artifacts and the student survey responses from those who dropped the course. Drafts of this paper were circulated widely among co-authors and stakeholders in the pilot course at the LPU as one means of ensuring the narrative record aligns well with individual memories of events—an approach known as pragmatic validation (Walther, Sochacka, & Kellam, 2013). Feedback from co-authors as well as other engineering education researchers not working on the project was instrumental to verify that the theoretical analysis and interpretation of events rings true—a process of theoretical validation (Walther et al., 2013).

Study Limitations

Presented in this paper are preliminary analyses with a limited dataset. The ethnographic focus on the course instructor, administrators, and researchers biases the narrative in favor of the actors who were empowered and incentivized to bring the WSM to the LPU, side-stepping the experiences of the students who remained in the course for the duration of the semester as well as the faculty and departmental entities who were not in favor of creating a WSM course at the LPU. The enrolled-student data is still being collected in the form of qualitative interviews and longitudinal tracking; hence, we save analysis of that data for future work.

We are reflective and aware of the tendency of classical *actor-network* studies to focus on the decision-makers and those in charge, rather than those at the network margins or those powerless to contest the processes of organizing, which are this paper's focus (Fenwick, 2011; Star, 1991). However, to address our research questions and begin to map the complex webs of processes of organizing at the LPU, we reason that utilizing the instructor and administrator data is a useful starting place to understand the organizing conditions that affect the implementation of a national educational model within a specific local context. Finally, we note that the work of analyzing the organizing processes of our institutions that influence new educational initiatives must be done before hindsight clouds memories, before the stories that are told about how a new class gets started subsume the actual events.

Findings

We describe the details of the processes of *translation* through which the WSM *Introductory Mathematics* course becomes *Engineering Math* at the LPU. Tracing this transformation across the four moments of translation, we describe the ways the original course model is modified and altered to suit the LPU before circling back to demonstrate the consequences of the way the course is classified within the systems and infrastructures of its new LPU context. To separate the ethnographic record of events from our interpretation of them, we provide both narrative and interpretation sub-sections within each of the four moments of translation presented below.

First Moment of Translation: Problematization—*Introducing the WSM to the LPU*

Problematization, the first moment of translation, refers to the defining of identities or roles for actors (both human and non-human) within an *actor-network* (Callon, 1986).

Narrative: A precursor to the WSM adoption is to motivate the faculty and administration at the new institution that the WSM course is worthy of testing—that its potential benefits outweigh its start-up investments. A newly appointed associate dean of undergraduate education, in partnership with other educational innovators at the institution, proposes a three-year initial pilot implementation of the course, and serves as a willing vocal and influential champion for bringing in the WSM, pointing to the dramatic improvements to engineering student retention realized at Wright State and other institutions. The WSM creator, Nathan Klingbeil, visits the LPU to personally explain program aspects and how it has been implemented at colleges nationwide, emphasizing the program's proven success at retaining students in undergraduate engineering programs regardless of incoming math preparation level.

At meetings with department chairs, degree-granting program directors, undergraduate advisors and curriculum committee delegates, the WSM is re-branded as *Engineering Math* and is discussed as having an established performance record, retaining students across the spectrum of prior math preparation (as represented by ACT math score), and is hoped to become a meaningful contributor to a broader college-wide initiative to *broaden participatio*n. Evidence is provided of the *Engineering Math* course's efficacy at retaining students, such as Figure 1, a slide from an LPU Undergraduate Education Council meeting.

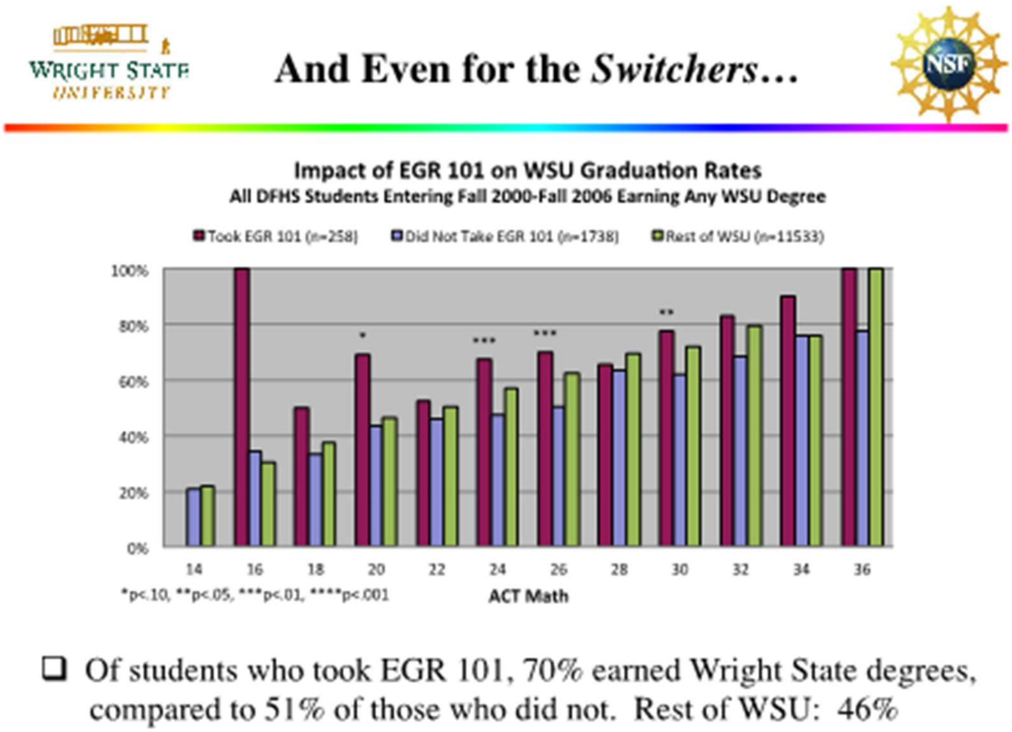

Figure 1. Excerpt slide from WSM presentation to the LPU Undergraduate Education Council.

To accompany this compelling data, the associate dean presents two mandatory *requirements for success* that the *Engineering Math*/WSM implementation at the LPU must possess in order to be a meaningful pilot and *true* replication of the original model—and in order to (hopefully) also attain duplication of the student retention gains.

1. The WSM course *must count* towards engineering degree graduation requirements.

2. Success in the WSM class *must count* as a prerequisite to subsequent courses in engineering majors, allowing WSM "takers" earlier access than their peers to technical courses as they simultaneously work through the *Calculus 1* and *2* series.

Interpretation: Calling these two criteria "requirements" evokes engineering terminology familiar to faculty and administrators, who will ultimately decide to pursue a pilot of *Engineering Math*, and makes it clear that *counting* for something along the curricular pathway is critical for the course's existence and legitimacy even in the pilot phase. The expectation that *Engineering Math* will be a replication or clone of the WSM is also part of the initial model definition, with an expressed focus on replicating the positive persistence and retention outcomes as the main motivations for bringing *Engineering Math* to the LPU. Additionally, the promise of *Engineering Math* to broaden participation in undergraduate engineering education by opening new access pathways for students previously classified as "underprepared" for engineering is another component of "the sell" to the LPU faculty and staff. Offering another access strategy to propel less-prepared students forward through the rigorous engineering curriculum is a compelling reason for the LPU to try *Engineering Math* and to get those in opposition to explore the broadening participation potential of this educational initiative.

Yet, also from the start, it is clear that duplicating all aspects of the WSM as it is implemented at Wright State will be a challenge within the LPU conventions and structures. The presentations to the Undergraduate Education Council thus define the WSM class and what it can be as *Engineering Math* within the LPU, creating (or *problematizing*) a salient course identity. The two "requirements" starkly define the necessary criteria for the course's survival, though they will continue to be refined as the pilot details are further negotiated through *interessement, enrollment* and *mobilization*—the remaining three moments of *translation.*

Second Moment of Translation: Interessement—*EGR 1010:* Engineering Math *Becomes ENGR 3800:* Special Topics

Interessement, the second moment of *translation,* describes the ways actors become interested, invested, or concerned in the problem outcome, as outlined in *problematization*.

Narrative: Recall that at Wright State, the course is called EGR 1010: *Engineering Math* and is the *required* starting point for *all* engineering students and thus the origin for *all* engineering curricula at the institution. The 1000-level course number designates it as the starting position for engineering and indicates its place of importance among the curricula. The *mandatory* class status is enforced and unquestioned; its status cannot be altered because it is institutionalized on curricular transcripts, flowcharts, degree requirements and other official university inscriptions. Thus, at Wright State, it is a "given" that all engineering students—regardless of prior math preparation—take this course to launch their engineering educations.

At the LPU, the course cannot be designated as a 1000-level course and still *count* for credit towards graduation because departments/programs are unwilling to modify the starting points for their undergraduate engineering curriculums to include a new, experimental course. LPU's first-year engineering curriculum is relatively standard across majors, including MATH 1350: *Calculus 1*, PHYS 1110: *Physics 1*, ENGR 1400: *First-Year Engineering Projects*, etc., and no additional first-year curricular requirements can be satisfied by this new course at the 1000-level across all engineering majors. The associate dean of education (ADE) comes up with a viable workaround: if the pilot course number is changed to 3000-level and the title is changed to *Special Topics: Engineering Mathematics*, it can count as an upper-division technical elective across all engineering majors and degree programs. This course number change enables the first requirement to be satisfied: it *counts* for something in the form of technical elective degree credit. Furthermore, the special topics prefix in the course name signals internally that it is an experimental course, not intended to be a permanent fixture in the course catalog.

To satisfy the second requirement, that the course must *count* as a prerequisite for subsequent engineering coursework, the ADA initiates a series of political maneuvers that have cascading consequences through the college, roughly following these chronological steps:

1. The engineering dean is convinced that the *Engineering Math* pilot implementation is a worthy educational initiative and agrees to broadly support the course, including the two requirements for success.

2. The engineering dean emails each engineering department/degree granting program

leader, requiring that each specify one course offering that students who pass *Engineering Math* will be permitted to subsequently enroll in concurrent to tackling *Calc 1* or *2*.

3. When some departments/degree programs are slow to act, the ADE and the *Engineering Math* instructor email follow-up messages and schedule individual meetings with departments/programs to identify the one course offerings that successful *Engineering Math* students will be granted subsequent early enrollment access.

4. Slowly, agreements are secured to enable *Engineering Math* to satisfy prerequisite requirements for at least one course per degree program.

5. For most departments/programs, the agreement stipulates simply that students who pass *Engineering Math* will be allowed to individually petition into designated courses, as this requires no explicit change to the prerequisite structure, course catalog, or curriculum flowcharts, while still satisfying the dean's request and the requirement that *Engineering Math counts* as some course prerequisite in each engineering major.

Interpretation: By the end of the negotiations with each department/program, the two requirements established in *problematization* for a successful pilot implementation of *Engineering Math* are ostensibly satisfied: the course *counts* towards graduation requirements across all undergraduate engineering majors and the course *counts* as a prerequisite to subsequent engineering coursework. Yet, the outcome of these negotiations is not a broad, universal acceptance of *Engineering Math* across the curriculum, rather it is a *narrowing* and *compression* of who and what the course *counts* for. Yes, it counts, but only for specific classes in specific majors for specific people that have to ask for specific permission.

The attainment of this level of specificity and specialization is notably the opposite of the way the class is situated at Wright State—a clear *mutation* of the WSM to make it fit at the LPU. At Wright State, because *Engineering Math* is the standard origin of every curricular flow for every undergraduate engineering major, the class is recognized by all actors in that network and noted in official inscriptions as *counting* for graduation requirements and for prerequisite requirements as well. This WSM aspect has been *mutated* rather than *replicated* in LPU's *Engineering Math*.

As a pilot, experimental course at LPU, the ENGR 3800: *Special Topics: Engineering Math* course does not have the same status and legitimacy that it has as EGR 1010: *Engineering Math* at Wright State. That the course has an official number and title that satisfies the requirements for success is an achievement and victory for the launch team and future students. Yet, it is important to note which course aspects have been modified in order to suit the existing LPU structures and systems, how the course is made to narrowly count for specific requirements on a petition-by-petition basis by individual students rather than accommodated globally by the full range of departments and majors. *Engineering Math* is beginning to gain a foothold at the LPU, but it is clearly tenuous and contingent rather than established and legitimate.

Third Moment of Translation: Enrollment—*Batch Enrolling and Student Un-Enrolling*

Enrollment, the third *moment of translation*, describes the processes wherein systems of alliances in an *actor-network* become confirmed.

Narrative: Once the agreements with each department/program are secured, the course number identified, and the course title adjusted, the requirements established for the pilot's success are satisfied and the course is officially created in the LPU recordkeeping systems. The course's official existence begins with an entry in the university's course catalog and opening the course to student registration. However, new questions arise. How will first-semester students find out about this pilot course? Who will sign up for a class that has never been offered before at this institution? Clearly, more allies are needed to advocate on behalf of the *Engineering Math* course to get students to enroll and stay enrolled.

The ADE calls on a team of undergraduate advisors and coordinators of first-year programs to aid in the course "messaging" or "marketing" to incoming first-semester, first-year students. Additionally, the institution's assessment director consults on how to select the enrolled student population for the course to enable robust research and retention comparisons, with an eye towards demonstrating "success" down the road for *Engineering Math*. Student selection criteria are established, primarily by the use of math placement scores indicating the *Pre-Calculus* level of prior math preparation, coupled with a desire to oversample from minority populations—including first-generation college attendees, Pell-grant eligible students, and women. A target number of 32 students is identified as optimal for the course pilot because that is the maximum number of chairs that fit in the classroom and lab specially designed and equipped for the course.

Since the students who meet the selection criteria are all incoming first-years who are new to the institution, the decision is made to "batch enroll" them before they arrive on campus, meaning that the registrar's office adds the 32 eligible students into the course rather than the students electing to add themselves into the course prior to the start of classes. After students are placed in the course, a *welcome message* email is sent to each student to explain the course and why they have been placed in it (see Figure 2).

The content of the *welcome message* is collectively written, reviewed and tweaked by numerous undergraduate advisors, coordinators of first-year experiences, the course instructor, the ADE, and the assessment director until it reaches its final form (Figure 2). Despite careful efforts to craft a persuasive message in support of *Engineering Math*, many batch-enrollees drop the course prior to the start of classes. After the initial summer batch-enrollment process, subsequent student enrollments are made by an academic advisor. Each time additional students are enrolled and the target of 32 students is reached, within a few days the number of enrolled students drops down to 25 or fewer as students choose to drop the class rather than stay in an experimental course they have heard little about—aside from the *welcome message*.

Congratulations—You have been selected to participate in a brand-new course called *Engineering Math*, which will be taught at LPU for the first time this fall! We have already added this course to your fall schedule. If you log in to the online portal, click on "Schedule" you will see this course, called ENGR 3800.

What's in this for you? The class is new, our active-learning classroom environment is new, and the equipment is all new and state-of-the-art. By semester end, you will have acquired a unique, cutting-edge foundation for your engineering education future. This foundation will help propel you forward through your engineering coursework and your undergraduate degree, as it is serving as a compliment to your *Pre-Calculus* class. ENGR 3800 will give you the potential to take courses such as *Physics I* and *Statics* earlier than if you were to take only *Pre-Calculus* this fall. Plus, the course counts towards your degree in all of the college's degree programs. And, with only 32 students in the course, *Engineering Math* will be fun, too!

In *Engineering Math*, you'll explore math concepts through hands-on labs that explore common engineering contexts and techniques. Each week, you'll see how a specific math skill from *Pre-Calc*, *Calc 1*, *Calc 2*, *Calc 3*, or *Differential Equations* is critical for such things as understanding circuits or predicting the behavior of mechanical systems. As you delve into engineering math in a team-based, hands-on environment, you'll be introduced to multimeters, oscilloscopes, and sensors; learn to program in MATLAB; collect and analyze experimental data in interesting ways—all while working collaboratively with (and getting to know!) other engineering students.

We are excited to have you be part of this new experience! As you are registering for your other fall classes, you may find that this class conflicts with other courses you need to take. While we hope you can create a schedule that will allow you to take ENGR 3800, we understand if you need to drop this class. If you do drop this class, you will take only *Pre-Calculus* in the fall. If you have questions about changing your schedule and registration, please contact your academic advisor. Should you have any questions specifically pertaining to ENGR 3800, please contact the instructor for this class: XXX@LPU.edu.

We look forward to meeting you in the fall!

Figure 2. The welcome message sent to students who were batch-enrolled into the *Engineering Math* course.

On the first day of class, around 30 students are enrolled; by the second week, only 23 remain. By the official drop deadline (~10 weeks into the semester), one more student drops the course, leaving 22 official enrollees to finish the semester.

In online surveys, students offer various reasons and justifications for dropping the course. Student responses to "What factors did you consider in your decision to drop ENGR 3800?" include:

- I was already enrolled in a math class and did not want that heavy of a course load for my freshman year.
- I didn't understand where the class came from, since I hadn't seen it during the pre-registration period, and I hadn't chosen it during the registration period. I thought it was a mistake in the system. The course description also didn't give me a good idea of the course material, and I didn't want to take a class that didn't provide a good description. It felt vague to me.
- I thought about the other classes I wanted to take initially and how it would work into my schedule. I also thought about the number of credits I had. For my scholarship I have to

have a certain amount of credits in order to be able to receive the full amount. If not then the entire amount would cut down to $2000 and some, or less.

- The factors that affected my choice in taking ENGR 3800 were the amount of classes I already have, as well as not knowing much about the class. I was not told much about the class so I didn't have much interest.
- I considered the number of credit hours [I] would be taking and how it would fit into my schedule. I am in another program on campus and with the class required for it, it made it impossible for me to take the class.
- I was unable to fit it in my schedule.

Interpretation: Comparing this *enrollment* process for the LPU pilot course with the established course at Wright State, the dominant difference in the optional vs. mandatory course status is readily apparent. Despite the efforts of LPU advisors, administrators, and course allies to communicate the course benefits to students, the students remain focused on the non-mandatory nature of the pilot class, the relative scarcity of available information about the course, and drop the class for numerous reasons. The *welcome message* reassurances are insufficient to convince students that the class is purposeful and will benefit them, and is not a "mistake" or a "vague" addition to their schedules.

The individual negotiations made in the process of *interessement* are not evident to students nor important to them because all they need to know is that the class is not required and no penalty exists for dropping it. Thus, the placement and positioning of *Engineering Math* within the larger system and curricular flows at the LPU is again a mutation of the system organization at Wright State. Even though the two requirements for success for the course pilot have been replicated dutifully in that the course *counts* towards graduation and *counts* as a prerequisite for subsequent engineering coursework, it is not enough to keep students from dropping the course.

Fourth Moment of Translation: Mobilization—*Which WSM Course Aspects Persist across Time and Space?*

Mobilization describes how an *actor-network* becomes moveable through space and time, examining how *actor-networks* are able to speak at a distance from the original actors involved.

Narrative: In order to move the WSM from one geographical place, time, administration, faculty, students, and curriculum to a new one with an entirely different context and separate recordkeeping systems, significant modifications and adjustments are made to the original model to gain traction in a new setting, as described in the prior three sections. Yet, in successfully piloting one semester of *Engineering Math* at the LPU, we find that the course itself has been *mobilized* across geographic distances, traversing the space from Wright State to the LPU while coordinating activity in both locations. The students enrolled in *Engineering Math* at the LPU are distinct from the students at Wright State; they are an entirely different set of individuals going through the same course during a similar semester timeframe, but separated by geographic distance and characterized by different demographics, campuses, and contexts. These students *mobilize* locally, circulating through class events, completing assignments and utilizing hands-on laboratory equipment, operating in parallel with students at other campuses with different WSM implementations.

Interpretation: To standardize the LPU course content and delivery with the WSM, *inscriptional* materials from Wright State are used, including the course textbook (Rattan & Klingbeil, 2014), homework assignments, laboratory assignments, lecture notes, and even exams. These curricular resources travel easily through time and space, as textbooks are easily shipped and electronic lecture notes, homework, lab, and exam files can be readily transmitted from Wright State instructors at to those at the LPU. While these course materials aid in duplicating the academic content, we find that they are only a small part of the overall organization processes that surround the pilot course implementation. The need to stay "true" to the original model is in line with the administration's hopes to successfully "replicate" the demonstrated course outcomes in encouraging access, persistence and retention in engineering majors—the overarching course goals from the outset (Figure 1).

However, the infrastructure surrounding the course and contextualizing it within a local environment does not transfer readily from Wright State to other institutions like the LPU. The negotiations made to adjust the course number and title to enable it to *count* towards degree programs at the LPU are one example of the adaptations and mutations required to implement the course in a new time and place, while still attempting to maintain coherence with the original WSM's core identity.

Discussion

From these narrative analyses and interpretations, we can begin to address our first research question: "What are the consequences—for students, instructors, administration and the course itself—of modifying aspects of the original course model, through active processes of adaptation and translation, to fit the needs and demands of new contexts?" In the Findings, we identified how the course attributes and related processes—including its number, title, status, and placement in the undergraduate curricular flowchart—were mutated from the WSM for instantiation at the LPU, with direct impact on how students view the course and their reasons for remaining in it or dropping it from their schedules. We also see the consequences for administrators in needing to sustain the course perception as a duplication and "true replication" of the WSM to aid in convincing local stakeholders and decision-makers that the course is an educational innovation worthy of implementing at the LPU. The promise of improving access, retention and persistence, of replicating the retention gains demonstrated at Wright State, is sufficient to compel individual departments to grant student access to subsequent coursework along their degree pathways, to satisfy the requirements for course success as initially *problematized* in the introduction of the WSM to the LPU. While departmental agreements are secured to enable the pilot course to *count* for credit along all LPU undergraduate engineering degree pathways and *count* for making progress towards degree attainment, we notice that this *counting* occurs in a fundamentally opposite structure than at Wright State. For students, this means the necessity of completing individual petitions to enable subsequent access to courses; for administrators, this means reminding the programs and departments of handshake agreements made during the planning phases—actions that are not required when the course is formally integrated into curricular structures like at Wright State.

As we continue to longitudinally track the performance of *Engineering Math* enrolled students over the planned three-year pilot implementation period, we await data that will reveal whether the persistence and retention statistics for students who complete the LPU *Engineering Math* course will replicate the success demonstrated at Wright State. Our analysis in this paper suggests that the replication of retention outcomes is not guaranteed because the LPU implementation of the WSM is as much a mutation as a true replication of the original model. As we have mapped and tracked the WSM attributes that have been modified, tweaked, and adjusted for LPU's *Engineering Math* course, we can only wait to see if student persistence will be a direct replication or a mutation from what is observed at Wright State.

Our second research question asks, "What is revealed about an institution and its processes of organizing when we closely examine what is required to replicate or mutate a successful national educational model within a local context?" The narrative details of the process of implementing *Engineering Math* at the LPU, as viewed through collaborator and external perspectives, have uncovered several unique characteristics of LPU institutional processes that were previously unquestioned or taken for granted by the research team and curriculum designers. For instance, the practice of "batch-enrolling" incoming students into *Engineering Math* emerged as a contentious institutional organizing process unfamiliar to colleagues from educational research rather than engineering backgrounds. The underlying institutional power structures that enable an unnamed registrar to add a course to students' schedules without first asking or notifying them of the change raised some eyebrows, causing the authors to reconsider the ethics of batch-enrolling and potential alternatives to this approach for future years of pilot implementation.

Similarly, the organizing processes through which the *Engineering Math* course becomes mandatory or optional demand further scrutiny. Our analysis shows the influence of this classification scheme on how students perceive the course, not to mention the practical consequences of this classification on how students will be compelled to enroll into the course and stick with it versus dropping it of their own volition. Those in power who ultimately decide on the optional vs. mandatory status of LPU's *Engineering Math* course are thus choosing more than an institutional classification; they are determining how the course will be formally situated within the existing LPU infrastructures and networks. They are choosing how the course will fit within the curricular and social trajectories of student navigation through undergraduate engineering. The policy choice of mandatory vs. optional also determines how closely *Engineering Math* at the LPU replicates the original WSM.

Additionally, this analysis encourages us to question whether it is wise and fair to determine the mandatory vs. optional status after only a single semester of administering the course. Does the LPU require a full understanding of its WSM implementation's persistence and retention outcomes prior to making this decision, or will the LPU's organizing conditions require a premature decision in order to schedule rooms and students accordingly? The focus on the organizing processes of the LPU across multiple levels highlights the implementation challenges of any new educational initiative when decisions must be made before having all the desired data. This analysis encourages transparency in decision-making processes for those who will ultimately determine the status of this fledgling experimental course, and encourages continued questioning about whether it is appropriate to base these decisions on what is officially perceived as a course replication but more realistically a mutation of the original model.

Our final research question asked, "What can engineering educators learn from this story of change to make impactful decisions for their own contexts, to prioritize certain transformations over others and enable smoother integration of new curricula into long-standing traditions and institutional structures?" Various models for change in engineering education and curricular reform have been popularized in the literature and through workshops administered by change experts (Henderson, Beach, & Finkelstein, 2012; Besterfield-Sacre, Cox, Borrego, Beddoes, & Zhu, 2014; Henderson et al., 2015; Rose-Hulman Institute of Technology, 2017). Published "action-guides" with recommendations on developing shared visions for innovation and taxonomies that categorize curricular reform efforts are interesting for engineering educators, but can be difficult to apply in practice. This analysis offers a different perspective—focused on the actual modifications and negotiations required of individuals and artifacts to move effectively from one context to another, highlighting the consequences of the trade-offs made as some elements move seamlessly from Wright State to the LPU, while others are left behind or reorganized within the new context.

Conclusions

In light of a national call to broaden participation in engineering education, the well-publicized and replicated results of the WSM compel all undergraduate engineering programs to at least consider implementing the program on their own campuses (Klingbeil et al., 2006). Convinced by the evidence from Wright State and other adopters, LPU endeavored to implement WSM in its engineering program with a three-year pilot course called *Engineering Math*. To bring structure to analyzing the process of implementing the WSM, we employ an actor-network model, with the adoption process considered as a translation (Callon, 1986; Nespor, 1994). This structure provided a worthwhile framework for highlighting replications and mutations in LPU's implementation of the WSM, as compared to the original. Within this framework, we found that certain inscriptional actors such as the curriculum, textbook, labs, and classroom equipment were easily mobilized and replicated within a new context. Significant differences, due primarily to the "pilot" and non-mandatory nature of the LPU implementation, were also exposed through use of this framework. Importantly, the two self-imposed requirements—that the course *counts* towards graduation requirements across all undergraduate engineering majors and the course *counts* as a prerequisite to subsequent coursework in engineering—were effectively implemented in a mutated and contrary manner to the original WSM.

As our analysis continues, we seek to expand our understanding of *Engineering Math* beyond the mutation/replication dichotomy towards understanding the course as a boundary object or boundary negotiating artifact (Lee, 2007; Star & Griesemer, 1989). Additionally, as the importance of classification systems has emerged through this narrative exposition of the *Engineering Math* pilot implementation, we plan to continue exploring the consequences of "sorting things out" as inspired by Bowker and Star (1999). Two more years of pilot implementation are planned at the LPU for *Engineering Math*; thus, continued attention will be paid to understanding if and how formal curricular structures and artifacts are adjusted to officially recognize and legitimize the course within the LPU context.

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