Using Theory to Scale Innovation in Higher Education: Supporting the Implementation of Multiple Mathematics Pathways and Corequisite Support in Arkansas

Andrew S Richman
Lesley University

Heather Ortiz
Oklahoma State University
Institute of Technology

Ahsan Habib Chowdhury
George Mason University

Eric Henry
Concord Academy

The Charles A. Dana Center worked across all public colleges and universities in Arkansas through a project called Strong Start to Finish (SStF) Arkansas to support the implementation of corequisite support for underprepared students in mathematics and multiple mathematics pathways for all. Consistent with Reinholz, White, and Andrews' (2021) call to more effectively ground change efforts in change theories, the Dana Center designed its innovation using a change theory-based theory of change. This preliminary report describes this project's outcomes and how the projects' results further the field's understanding of Rogers' Diffusion of Innovations theory, one of the change theories on which the project's theory of change was based.

Keywords: Change Theory, Diffusion of Innovation, Corequisite Support, Multiple Mathematics Pathways, Higher Education

Introduction

STEM higher educational change is complex, multi-faceted, and a necessary constant to improve access, teaching and learning, and outcomes for diverse educational stakeholders. Although long-term research has documented innovation and outcomes for STEM projects emphasizing STEM higher educational change, fully scaled sustained change in these projects is less known. Furthermore, change efforts have rarely used change theory to directly inform their work, making it difficult to build knowledge across the field (Reinholz et al., 2021).

Reinholz, White, and Andrews (2021) have called for change efforts to more effectively rely on theory by using both *change theories* and *theories of change*. Reinholz and Andrews (2020) defined a change theory as a broad framework of ideas that employs theoretical and empirical knowledge to explain some aspect of change. They defined a theory of change as project-specific and connected to evaluation; it explicitly promotes underlying assumptions about how and what change will occur in a defined project and then uses desired outcomes to guide project planning, implementation, and evaluation. A single change theory can support multiple components of a theory of change, and a single theory of change can draw from many change theories. The call by Reinholz, et. al. urged change efforts to create theories of change that are directly informed by change theories so that the results of projects can be used to build fieldwide knowledge.

The Charles A. Dana Center at The University of Texas at Austin's Mathematics Pathways Project (DCMP) is a national STEM higher educational change initiative that has employed a theory of change to create broad, deep, and sustainable change in undergraduate mathematics pathways. The Dana Center based the projects' theory of change on four change theories and used the theory of change to design and implement this national change effort. In this preliminary research report, we will describe one element of this theory of change (the part based

Rogers' (1983) Diffusion of Innovation Theory) and how the interventions based on this theory of change impacted state-, region-, and institution-level reform across Arkansas public colleges and universities. We will show how the results of this intervention can be used to inform thinking about the change theory on which it is partially based. We will investigate the research question: *What can be learned about Rogers' Diffusion of Innovation Theory for STEM higher educational change by looking at the results of the DCMP project in Arkansas*. Future publication by the authors will address all four change theories used to create the DCMP theory of change.

Theoretical Framework

Change Theory

The DCMP project drew on four change theories to build their theory of change (Ortiz & Cook, 2019). In this paper, we will focus on the aspects of the theory that utilized Rogers' Diffusion of Innovation theory (DoI). In this section, we will discuss the aspects of Rogers' (1983) theory that are relevant to the theory of change.

Rogers described classifications of potential adopters of a new idea by how quickly they adopt innovation — a characteristic Rogers referred to as *innovativeness*. The quickest and slowest groups (*innovators* and *laggards*) are the smallest—estimated at 2.5% and 16% of the population respectively. The middle three groups (*early adopters, early majority,* and *late majority*) comprise the bulk of the population—estimated at 13.5%, 34%, and 34% of the population respectively. He characterized innovators as able to tolerate a high degree of uncertainty about an innovation at the time they adopt it. In contrast, even early adopters require higher amounts of legitimization to adopt a new idea.

Rogers described two different structures of diffusion systems: systems in which innovations originate from experts or other authoritative sources and then spread, or do not spread, to potential users without alteration (*centralized*), and systems in which innovations are created by users and spread to other users who may adopt the innovation as is or may alter it to suit their circumstances (*decentralized*). He pointed out that decentralized systems are likely to create innovations that better fit with the needs of the users and that users are more likely to take ownership of the innovation – creating deeper and more sustainable change. However, he argued that a centralized aspect of a system can be important if users are not aware of a need for innovation or if there are larger centralized structures that need to be modified to enable the innovation to operate effectively in the larger system.

Lastly, Rogers described how the nature of relationships between individuals in a social system impacts how innovations spread. When most communication in a system is between individuals that are similar in attributes such as beliefs and social status, etc. (homophilic communication), diffusion is hampered. This is because earlier adopters tend to have different beliefs, communication styles, economic status, and social status than later adopters. If there is little communication between people who are different (heterophilic communication), there will be no route for innovation to spread beyond the early adopters.

DCMP Theory of Change

Following Reinholz (2020), we organize our description of the DCMP theory of change by first discussing the context of the project, then the assumptions that connect the DCMP theory of change to DoI, then the intervention, and then indicators that were used to judge the success of the intervention and the validity of the change theory.

Context. Following a national call to action to modernize undergraduate mathematics, the state of Arkansas joined the Dana Center in 2015 in a multi-state initiative to lead a mathematics faculty task force to develop and publish recommendations that addressed barriers to equitable access and success in undergraduate mathematics. In 2019, the Dana Center expanded this work in Arkansas through the Strong Start to Finish Arkansas (SStF) initiative, which strategically coordinated three state-level agencies and two national advocacy organizations to collectively lead the work. The multi-prong leadership approach intentionally pulled together change agents within the state of Arkansas to help set the pace, process, and conditions for implementing and scaling mathematics pathways[1] and corequisite supports[2], creating a 'coalition of the willing' across state-, region-, and campus-level communities and actors.

Assumptions. Three assumptions of the DCMP theory of change were drawn from Rogers' DoI. The first is that *high-profile legitimization of change is an important factor in the decision-making of early and late majority adopter types.* This assumption is based on the relative conservatism that Rogers associates with all adopters aside from innovators. If an innovation is to spread past the 2.5% of the population that are innovators, it will be helpful if said innovations have support from influential regional or national stakeholders. The second assumption of the DCMP theory of change drawn from Rogers' DoI is that *deep, broad, and sustainable scaling requires a combination of top-down and bottom-up approaches.* This is based on Rogers' description of the advantages and disadvantages of centralized and decentralized diffusion systems. The third assumption is that *broad scaling requires initial change efforts to be distributed across the higher education ecosystem.* This is based on Rogers' contention that change does not diffuse well between different types of institutions (Rogers, 1983); an initial focus on any particular type of institution will limit the prospects for widespread dissemination.

Intervention. To achieve the SStF project outcomes, guided by the DCMP theory of change and its underlying change theories, The Dana Center worked across state, region, and institution levels. At the state level, interventions focused on two separate policy areas: (1) support state-level transfer and applicability work to expand implementation of Quantitative Literacy (QL) recommendations, and (2) establish a new task force on secondary-postsecondary mathematics alignment. At the region level, Dana Center interventions leveraged a previously established system of regional coordinators who strengthened their college and university partnerships. Each regional coordinator supported both breadth and depth across their assigned institutions through coordinated project activities that focused on transfer and applicability, secondary-postsecondary alignment, mathematics pathways and corequisite support implementation, local leadership capacity, and data-driven decision-making. Last, institution-level interventions focused on building depth of knowledge and leadership capacity within institutions. The Dana Center supported both individuals and institutions through multi-institution professional learning opportunities for mathematics faculty, academic advisors, and mid-level administrators. This professional development increased capacity in key roles, so practitioners were better positioned to lead and serve as models for others.

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[1] Mathematics pathways are a mathematics course or sequence of courses that students take to meet the requirements of their programs of study. This concept applies to college-ready and underprepared students.

[2] Corequisite support refers to placing students who have been designated as underprepared directly into college-level courses and providing necessary additional support to help them effectively engage with the college-level coursework.

Indicators. Broadly speaking, the SStF-identified indicator of success was that all Arkansas public institutions of higher education would implement at least two mathematics pathways and 75% of underprepared students would be enrolled in corequisite support. For this analysis, we adopted three additional indicators to examine the extent to which the assumptions of the DCMP theory of change held. These were: (1) whether high-profile legitimization occurred and, if so, whether it was an important factor in the decision-making of potential adopters, (2) whether both top-down and bottom-up approaches were used and, if so, whether the combination impacted the depth, breadth, and sustainability of change, and (3) whether change efforts were distributed across a variety of institutions and if so did this enable broader scaling or is there evidence that heterophilic communication occurred, reducing the need for distributed initial change efforts.

Methods

Quantitative data was collected annually in 2020, 2021, and 2022. All public colleges and universities in Arkansas submitted a SStF Arkansas Data Collection Workbook which gathered data about degree-seeking students relevant to academic placement for mathematics, student enrollment and success in remedial mathematics in students' first year of college, and student enrollment and success in introductory college-level mathematics in students' first year of college.

Qualitative data was collected through ten 45- to 60-minute conversations each with between one and eight faculty and/or administrators. Fourteen institutions were represented, seven two-year and seven four-year institutions. Participating institutions were chosen in consultation with the regional coordinators to represent a range of experiences implementing mathematics pathways and corequisite support. Participants were asked about the extent to which multiple mathematics pathways and corequisite support had been implemented in their institutions, and about supportive and inhibiting factors in the implementation. Data addressing the second question was analyzed using thematic analysis (Braun & Clarke, 2006).

Findings

In order to assess the validity of the theory of change we must first look at whether change happened. The data suggests that mathematics pathways and corequisite support were implemented widely but, in many cases, not deeply. Every one of the fourteen institutions that participated in qualitative data collection offered corequisite support for college-level mathematics classes and had at least one pathway in addition to College Algebra, most commonly a quantitative literacy (QL) pathway. Statewide progress is being made in increasing enrollment in corequisite support and shifting student enrollment to multiple pathways. The statewide percentage of underprepared students enrolled in mathematics corequisite support increased from 55% in 2020 to 72% in 2022. The percentage of students in college algebra decreased from 69% in 2021 to 66% in 2022. It was lower in 2020 (59%) due to many community college students taking non-transferable classes – an issue that began to be addressed in 2021. Despite the prevalence of QL pathways and corequisite support, about half of the institutions represented in the conversations reported that the QL pathway was underutilized, and most institutions offered only corequisite support for QL classes but still required prerequisite developmental classes for some students taking College Algebra. Most of the institutions that participated in conversations reported that about 30% of students who required academic remediation for College Algebra took prerequisite classes.

Participants in the conversations reported that high profile legitimization did occur and was an important factor in stakeholder decision making. This legitimization took a variety of forms

including (1) state education department expectations, (2) Dana Center advocacy, (3) example setting by peer institutions, and (4) the legitimacy of four-year institutions' adoption of mathematics pathways and corequisite support for two-year institutions.

Participants also reported advantages of the top-down, bottom-up intervention approach by the Dana Center. Advantages of the top-down approach were (1) the power of the state to push for change, (2) supportive accountability from the Dana Center in the form of data provision and check-ins from regional coordinators, (3) the ability of the Dana Center to spread information about the innovation including basic concepts, data that supported its feasibility, and technical assistance to support implementation, (4) logistical support from the Dana Center such as small amounts of funding and protected meeting time, and (5) the importance of four-year adoption in assuaging transfer concerns by two-year institutions. Advantages of the bottom-up aspects of the approach were (1) much of the persuading at the local level came from colleagues citing local data, and (2) local advocates could work out local issues such as strengthening communication between faculty and advisors, initiating curriculum review to establish need, creating course teams to support implementation, and navigating institutional politics.

Finally, participants described the advantages of distributing change efforts across institutions with some qualifications. Working with a variety of institutions ensured that the top-down aspects of the effort reached everyone. Furthermore, multi-institutional convenings enabled heterophilic communication. However, there is evidence that some heterophilic communication would have occurred in the absence of these convenings. Transfer issues require two-year institutions to pay close attention to what is happening in four-year institutions. It is unclear, however, whether an innovation that starts with two-year institutions would migrate to four-year schools.

Discussion

Thus, although SStF successfully supported change in Arkansas, its full-scale goals have not yet been completely realized. Multiple mathematics pathways and corequisite support have spread broadly in the state but could still be deeper within the institutions. The parts of its theory of change based on Rogers' DoI theory (1983) were largely shown to be valid with some exception. High-level legitimization was, indeed, important as was the combination of the top-down, bottom-up intervention design. It is less clear that initiating change across the institutional landscape was the only way to spread the innovations broadly. This suggests that Rogers' characterization of most potential adopters as conservative and needing external legitimization has merit as does his description of the affordances and constraints of centralized and decentralized diffusion systems. It is less clear that his concern about the diffusion-preventing character of homophilic communication systems applies to higher education in Arkansas. More research will be needed to illuminate this last question. What is clear is that Reinholz, White, and Andrews' (2021) call has merit. Creating a theory of change based on change theory(ies) and then building an intervention using the theory of change can enable a change effort to efficiently inform theory and provide usable information to the field about how change happens.

Questions for the Audience

1. What do you believe it means to have a change theory directly or rigorously inform a theory of change?
2. Please give us feedback on our effort to inform change theory.
3. What do you think of the call by Reinholz et al. for STEM higher education researchers and do you structure your change efforts in this way?

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