Understanding the Implementation and Impacts of an Innovative Corequisite Math Course

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This paper explores findings from a quasi-experimental study, focusing on the implementation and impacts of an innovative corequisite mathematics intervention. Conducted in a large U.S. community college, the study is evaluating the impacts of the Statway Corequisite course on student outcomes compared to the business-as-usual statistics corequisite course. Preliminary analyses show positive student outcomes in courses using the curriculum. The paper investigates the extent to which key implementation fidelity components are associated with those outcomes. These components include the use of a contextualized curriculum designed to be relevant to students, incorporating student collaboration in online and in-person classes, and addressing the social-emotional and academic needs of students. Understanding the impact of these components on student outcomes has implications for the design of corequisite mathematics coursework.

Keywords: Corequisite, fidelity of implementation, mathematics curricula, social-emotional learning, pedagogy

This paper focuses on understanding the implementation and impact of an innovative corequisite mathematics intervention in a large-scale quasi-experimental study. Conducted in a large U.S. community college, the goal of the study is to evaluate the impacts of the Statway Corequisite course on student outcomes and to understand the implementation components that relate to those outcomes.

Background

Over the last two decades, evidence has shown that structural changes such as math pathway implementation and corequisite model adoption have helped more students advance to, and succeed in, college-level math than traditional models of developmental remediation (e.g., Jenkins et al, 2021). That evidence has led to many states, including Tennessee, Texas, Louisiana, and California, championing corequisites in their developmental education strategies and to many colleges incorporating multiple math pathways for students to earn college math credit (Education Commission of the States, n.d., Hodges et al., 2020).

Statway Corequisite is a statistical reasoning curricular offering developed by Carnegie Math Pathways (CMP) at WestEd. It is designed as a one-term college-level course with a corresponding corequisite support course that aims to accelerate students through a college-level statistics course in a single semester. The college component of Statway Corequisite covers the learning outcomes of standard introductory college statistics courses, supporting both in-person and online formats. The foundational concepts and skills needed for success in the college-level lessons are included in the corequisite component (e.g., percentages, simplifying expressions, probability, etc.). Statway Corequisite combines a contextualized curriculum grounded in realworld application with an active, collaborative learning approach and student supports that help build learner mindsets and a sense of belonging.

Statway Corequisite instructional design is based on research on teaching for understanding and the development of mathematical practices (Bransford, Brown, & Cocking, 2000). The Statway Corequisite pedagogy emphasizes productive struggle with challenging problems (Schmidt & Bjork, 1992); making conceptual connections explicit (Hiebert & Grouws, 2007); deliberate as opposed to routine practice (Ericsson, 2008; Pashler, Rohrer, Cepeda, & Carpenter, 2007); opportunities for rich mathematical discourse (Moschkovich, 2007); and collaborative learning in promoting mathematical sense-making (Esmonde & Langer-Osuna, 2013; Webb, 2009).

Statway Corequisite Design Principles

The design principles for Statway Corequisite approach to curriculum, pedagogy, and student supports include the following:

Students feel that the course has value. Many students who have struggled with math often question the value of mathematics in their daily lives and long-term goals. Statway Corequisite is designed to help students see this value through a curriculum that includes relevant contexts that students see as personally engaging (Hulleman & Harackiewicz, 2009). Given the curriculum's emphasis on relevance and engagement, instructors are discouraged from introducing other, more traditional materials and approaches. In implementing the course, the focus is on depth into core ideas and skills rather than coverage of the full curriculum.

Instructors engage students in collaborative group work. Modeled after typical mathematics lessons in Japan (Shimizu, 1999), the instructional approach relies on small group, collaborative work within the four phases of a Problem Cycle: The Problem Launch to prepare students for productive struggle, Working the Problem in small groups, Discussing the Problem to make public students' thinking, and Conclusion to highlight the key concepts drawn from student thinking. The Problem Cycle provides a structure for instructors to facilitate group work by preparing students for collaboration and bringing ideas together that surface during the collaborations. Students collaborating in groups is key to this approach and is often an indicator of its use. The online version of the course requires students to meet synchronously to collaborate on the lessons' problem situations. Student interactions throughout the online lessons and debriefs are recorded and shared with the instructor, who then responds accordingly.

Students demonstrate Productive Persistence, or the combination of tenacity and good strategies. Research has shown that psychological aspects such as mindsets, "grit" or passion, and perseverance for long-term goals, self-control, and engagement are important predictors of academic achievement (Dweck, Walton, & Cohen, 2014). Statway Corequisite's approach supports these non-cognitive factors through a collection of Productive Persistence activities and routines, including a growth mindset writing activity, a contract activity to develop a sense of belonging, supports for forming groups to strengthen student ties, and instructor email routines that foster a sense of community.

Framing Fidelity of Implementation

Program fidelity is typically defined as "how well an intervention is implemented in comparison with the original program design" (O'Donnell, 2008, p. 22). The level at which a program is implemented with fidelity is often related to the results (Hill & Erickson, 2019). Various frameworks for fidelity exist in literature (e.g., O'Donnell, 2008; Century et al., 2010; Bos et. al, 2023), with most rooted in the five factors proposed by Dane and Schneider (1998):

Adherence to the intended program, exposure to the program, quality of delivery, program differentiation between conditions, and student responsiveness to the program.

For this project, we focused our definition of fidelity on the elements of the course related to its design principles, roughly aligning them with Dane and Schneider's framework elements of adherence, student responsiveness, and program differentiation, as summarized in Table 1. Assessing the quality of delivery was outside of the scope of the project. Elements of exposure, such as students engaging in Productive Persistence activities, overlapped with adherence and were not analyzed separately. In addition, since the focus of the curriculum is depth, not breadth, traditional indicators of exposure, such as the number of lessons completed, do not directly apply. For **adherence**, we focus on the teachers' implementation of the course design principles: (1) the primary curricular resource used is Statway Corequisite, designed to be relevant and valuable to the student population; (2) whether or not teachers use group work, and (3) whether or not teachers teach the Productive Persistence lessons that designers designated as essential. **Student responsiveness** focuses on whether students report the math class, as implemented, being relevant, and whether they show improvement in non-cognitive outcomes related to productive persistence. As well as being a fidelity indicator, improvement in non-cognitive outcomes is also a secondary outcome measure of the full study. Student responsiveness would also include whether students engaged in collaborative work, which is being measured in adherence. **Program Differentiation** looks at what is the same or different between the treatment and control conditions for the key elements of fidelity. We will look at similarities and differences in the curricula taught, rates at which teachers' use group work, differences in students' report of math class relevance, and differences in students' non-cognitive outcomes.

Table 1. Fidelity of implementation of the Statway Course.

Fidelity factor	Key components		
	Students feel that the course has value	Instructors engage students in collaborative work	Students demonstrate productive persistence
Adherence	Teacher uses Statway	Teacher uses group work	Teacher teaches required productive persistence activities
Student Responsiveness	Students report math class is relevant	[See Adherence]	Students' non-cognitive outcomes improve
Program Differentiation	Difference of curricular materials Difference in students' report of math class relevance	Difference in rates teachers implement group work	Difference in students' non-cognitive outcomes by condition

While student responsiveness and program differentiation are important, this paper focuses on describing the fidelity in terms of adherence, with the presentation also including treatment impact analyses using adherence fidelity as a moderator.

Methods

Study Context

This fidelity of implementation analysis is set within the context of a large-scale quasi-experimental study of the impact the Statway Corequisite course has on student outcomes, such as grades and persistence. The research team partnered with a large community college system in the Southwestern United States and spanned eight academic terms. The study team collected baseline data on students' prior math achievement and demographics, and course-taking outcomes (grades, credits). In addition, the team collected data outlined in the "Methods" section to assess fidelity of implementation, non-cognitive student outcomes, and to understand other contextual factors.

Results of the quasi-experimental design (QED) study, with a sample of over 1,800 students, indicate that students in the treatment course, in comparison to business-as-usual students, earned higher course grades (ES = 0.51, $p < 0.001$); were almost 50% less likely to earn a grade of D, F, incomplete or withdraw from the course (DFWI) compared to business-as-usual ($p < 0.001$); and, though non-significant, were about 20% more likely to complete the course. (Walters et al., in press). The current paper explores fidelity components that may have led to these promising results, with the presentation also examining whether the treatment impact varies by level of fidelity.

Study Design

The preliminary quasi-experimental analysis was conducted with 1,861 students (771 in Statway and 1,090 in business as usual) across multiple campuses of a large community college system. This paper focuses on adherence fidelity components directly under teacher control, which applies only to the treatment teachers in the main sample. The research questions are:

- To what extent is Statway Corequisite implemented with adherence fidelity?
- Does the treatment impact vary by the level of adherence fidelity?

Analysis related to the second question will be included in the presentation.

Teachers were chosen as a unit for analysis because we did not see meaningful variation from term to term with respect to the fidelity components. The sample for fidelity analysis included 17 treatment instructors, where 10 taught in person and seven taught both in person and online. Each instructor taught up to three sections each of the eight study terms. Class sections varied between three and 18 students, with a total of 49 in-person sections and 14 online sections.

Over the course of each study term, all teachers were asked to complete logs and then complete a post-term survey at the end of the term. Most, but not all, teachers of in-person sections were observed one time each term and interviewed soon after the observation. Teachers of online sections were interviewed in the second half of the term. At the end of the study, all treatment teachers were asked to complete a fidelity survey. In addition, treatment students' online platform usage records were collected for all but two terms.

Data Sources

The data sources are detailed below. Unless otherwise noted, treatment and control teachers completed both using the same protocol.

Instructor Fidelity Survey. This survey was administered to treatment teachers after the completion of other study activities. Teachers were asked the percentage of course materials used that were Statway Corequisite, if group work was used, and which Productive Persistence activities (e.g., email routines and forming groups) they implemented in their classroom.

Post-Term Instructor Survey. The post-survey was administered at the end of each semester and included questions about teaching practices, such as the use of small groups.

Instructor Logs. Logs were administered six times in the fall and spring semesters and four times in the summer terms, approximately every two weeks. Log questions included how often students worked in small groups. Responses were averaged for each teacher and each term that they taught a study course.

Observations. Trained researchers observed classes during all semesters, excluding the short summer terms. They observed each teacher's in-person class at least once over the course of the study and often once within each term they taught. The team coded the observations using the Toolkit for Assessing Mathematics Instruction – Observation Protocol (TAMI-OP), a matrix covering a variety of teacher and student behaviors in the classroom divided into two-minute intervals (Hayward, Laursen, & Weston, 2021). The two main indicators of fidelity were the percentage of class time in which the variables "WG" (Working in groups on structured group work) and "OG" (Other group activity, such as a Think/Pair/Share) were coded.

Interviews. Most teachers participated in one interview a term. Interview topics included describing a typical lesson, differences between a typical lesson and the observed lesson, any modifications made to the curriculum, and any social-emotional lessons taught.

Course Usage Data. Usage data from the online homework platform included records of which students attempted college and corequisite exercises. The number of exercises attempted per student for the college and corequisite components was then averaged for each teacher and term.

Fidelity Measures

For each adherence fidelity component, teachers' implementation was rated as "Meeting Standards" or "Not Meeting Standards," as specified below. In rare instances, interview data were used to adjust ratings if there was strong evidence of meeting or not meeting the metrics. The metrics for meeting standards are:

Uses Statway. Reported on the Fidelity Survey, that 90% or more of the course materials were Statway course materials, and, on average, students completed 20 or more Statway exercises per term. If usage data are unavailable for all terms a teacher taught, the rating is based on the Fidelity Survey.

Uses Group Work. Meets three or more of the metrics in Table 2 below. Using multiple measures helps to account for missing or inconsistent data.

Table 2. "Uses Group Work" Fidelity Metrics

Fidelity Metric	
Online	In Person
Fidelity Survey: On a 3-point scale, teachers reported students working in groups "Occasionally" or "Regularly."	**Observations:** Group work codes WG and OG comprised 25% or more of the observation class time. **Logs:** On average across responses, teachers reported students spending 25% or more of class time working in groups.
Logs: On average across responses, teachers agreed or strongly agreed, on a 4-point scale, that "The majority of my students are consistently engaged [while] working in small groups."	
Post-Survey: On a 4-point scale, teachers reported students working on math problems together in small groups, "Most of my classes," or "Almost all of my classes."	

Teaches required Productive Persistence activities. Reported on the Fidelity Survey, teaching three of the four required Productive Persistence lessons.

Findings

All treatment teachers' implementation met metrics for at least one adherence fidelity component, with all but two teachers (92%) meeting metrics for two or more adherence fidelity components. However, roughly half of the treatment teachers' implementation met metrics for all three adherence fidelity components. Metrics indicate a higher percentage of in-person teachers implemented each fidelity component than online teachers, though the percentage difference is minimal (2% – 7%). There were also high rates of meeting fidelity metrics across all adherence fidelity components, with the total percent of teachers meeting metrics ranging from 75% to 88%. These results are summarized in Table 3.

As mentioned above, the main study's findings indicate students have stronger positive outcomes in the treatment course as compared to the control course, likely due to the implementation of these three adherence fidelity components: using the Statway curriculum, using group work in lessons, and teaching the required Productive Persistence lessons. Additional analyses incorporating these components into the analytic model will be included in the RUME presentation.

Table 3. Teachers meeting fidelity metrics across the sample

		Fidelity component			Number of fidelity components		
		Uses Statway	Uses Group Work	Teaches Required PP Lessons	One or more	Two or more	Three or More
Online	N Meeting	5	5	6	7	6	3
	% Meeting	71%	71%	86%	100%	86%	43%
In Person	N Meeting	15	13	15	17	16	10
	% Meeting	88%	76%	88%	100%	94%	59%
Total	N Meeting	20	18	21	24	22	13
	% Meeting	83%	75%	88%	100%	92%	54%

Implications

The positive QED findings, coupled with the high rates of fidelity of implementation, indicate the key components of the treatment course are likely related to positive student outcomes. Beyond the adoption of this particular course, this has implications for improving all corequisite mathematics courses. Use of curriculum with problem contexts designed to be relevant to students increases interest and engagement, while also helping students connect mathematics use to their lives, to their studies, and future goals. Incorporating collaborative learning strategies that foster mathematical discourse, give students' voice and agency, and provide opportunities to build habits of mathematical reasoning. Practices and routines that promote safe and supportive group learning nurture students' sense of belonging in the classroom, helping them to productively struggle and persist through the course. Addressing all are important for improving student outcomes (Huang, M., 2018).

More broadly, this study demonstrates the importance of measuring fidelity in large impact studies. Without such data, it is impossible to understand the factors that may contribute to an intervention's success and can be used to scale the intervention in other contexts.

Conclusion and Next Steps

This study demonstrated positive student outcomes associated with the Statway Corequisite course, likely due to the course design and use, incorporating student collaboration in online and in-person classes, and addressing the social-emotional and academic needs of students. Additional work will investigate fidelity components related to student responsiveness to confirm and uphold the results from adherence. Program differentiation will be analyzed to further confirm and illustrate any meaningful differences between the treatment and control implementation.

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