International Journal of Research in Undergraduate Mathematics Education
https://doi.org/10.1007/s40753-023-00226-y

Exploring the Impact of the Corequisite Classroom Climate on Students' Attitudes Toward Mathematics

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Accepted: 1 September 2023

Abstract

Many postsecondary institutions across the United States have adopted the corequisite model of academic support to facilitate student learning and the successful completion of introductory mathematics courses within students' first year of college enrollment. While research have highlighted the benefits of corequisites in terms of academic outcomes, there is little qualitative research on the impact of this model of academic support on students beyond course grades. Through student narratives, this study documents how one university implemented their College Algebra corequisite and investigates the impact of the classroom climate of a corequisite course on students' attitudes toward mathematics. This study shows that though the classroom climate positively impacted the participants' attitudes toward mathematics in general, the climate of the corequisite specifically had a greater impact on their beliefs about mathematics and perceptions of themselves as learners of mathematics. However, there were some identified drawbacks to the corequisite course including time-consuming coursework and occasionally unproductive group collaboration. These findings highlight the potential for corequisites to foster positive attitudes toward mathematics, yet it also demonstrated a need for greater intention in the course development to ensure a coherent course structure where course activities and assessments give way to meaningful and productive student engagement.

Keywords Corequisite · Academic support · Attitudes toward mathematics · Classroom climate · Gateway mathematics

Introduction

There is some consensus in the mathematics education field that there is a mismatch between our expectations of student mathematical abilities upon entering postsecondary education and student academic performance in introductory college

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courses. For instance, Grubb et al. (2011) suggested that a large share of incoming freshmen begin their college journey with underdeveloped algebra skills. This issue often arises within gateway mathematics courses – which are introductory mathematics courses that are required for many Science, Technology, Engineering, and Mathematics (STEM) majors. Given the relationship between failure in gateway mathematics courses and attrition in STEM fields (Chen, 2013; Complete College America, 2012; Kovacs, 2016), a focus on academic support programs for gateway mathematics courses is an important cause for addressing systemic problems related to retention and completion of students at postsecondary institutions. Academic support programs are institutional mechanisms for helping students develop requisite skills for learning and/or mastering relevant course content. This paper focuses on one such academic support mechanism, the corequisite model, within the context of a postsecondary institution within the United States.

The Corequisite Model

The corequisite model, also referred to in other literature as corequisite remediation (Rutschow & Mayer, 2018; Vandal, 2018) or concurrent learning experiences (Arendale, 2010), is a model of academic support where students simultaneously enroll in a credit-bearing course and a workshop that equips them with the tools to successfully participate in their credit-bearing course. The corequisite model has functioned as a departure from the traditional developmental education sequence of prerequisite courses (i.e., remedial coursework), where students can now attempt credit-bearing coursework earlier in their academic journey. In fact, various state governments and institutions within the United States (e.g., California, Connecticut, Florida, Tennessee, Texas) have made declarations, established mandates, or issued incentives for postsecondary institutions to provide incoming students academic support in the form of corequisites to enable students to attempt and complete their courses within their first year of college (Bracco et al., 2019; Brower et al., 2018; Daugherty et al., 2018; Vandal, 2018).

Various research studies have supported the use of corequisites to support student learning and course completion. In comparing students who were enrolled in an Elementary Algebra with and without a corequisite workshop, Logue et al. (2016) found that students who were enrolled in a course with a workshop performed better than their peers who were not. This finding was not statistically significant. However, another study (Kashyap & Mathew, 2017) did find statistically significant higher course outcomes for students who took a Quantitative Reasoning course with a corequisite support as opposed to one without. Similarly, Smith (2019) found that a greater percentage of students (about 73%) enrolled in a College Algebra corequisite passed the course when compared to those who did not (about 56%).

There is not a wealth of research on students' experiences and perceptions of the corequisite model. In this manuscript, the *student experience* is conceptualized by how students engaged, perceived, and were affected by their learning environment. This includes perceptions on the time spent in their classroom, their perceptions on the classroom environment and content presentation, as well as their engagement with their instructor, peers, and the course content. Applying the theory around student voice (e.g., Robinson & Taylor, 2007), this current study acknowledges the importance of considering the student voice in enacting new educational reforms. Considering the student experience, Pintrich and Blumenfeld (1985) illustrated how certain aspects of the classroom experience – specifically teacher feedback – can potentially impact students' attitudes toward learning. As participants and intended beneficiaries of educational reforms such as the corequisite model, it is essential for students' lived experiences and perspectives to be explored and critically examined.

The current literature on corequisites suggests that students may prefer corequisite courses as opposed to a developmental education sequence, as evidenced by Kashyap and Mathew (2017), and Fay (2018). In a study by Kashyap and Mathew (2017), 155 freshmen were placed (i.e., assigned a given course by the institution) in either a one-semester Quantitative Reasoning course, a two-semester prerequisite course followed by a Quantitative Reasoning course (a prerequisite model), or a one-semester Quantitative Reasoning course with a corequisite support (a corequisite model). The students in the prerequisite model were provided instruction on prerequisite content for their Quantitative Reasoning course in the first semester, and then took the Quantitative Reasoning course in the second semester. On the other hand, the students in the corequisite model were provided instruction in Quantitative Reasoning during a single semester and received targeted instruction on prerequisite material as needed during that semester. Through an anonymous survey distributed at the end of the semester, 80% of the students in the corequisite model responded positively about their time in the course, compared to only 30% of the students in the prerequisite model.

In their study at a two-year institution where about 70% of the students were identified as needing developmental education, Fay (2018) observed that students found the pacing more manageable than prior remedial courses attempted. Students positively perceived the additional course material despite faculty expressing concern around the breadth of material that is covered in a corequisite course (e.g., course content and developmental education content). In another study at a four-year institution, Hancock et al. (2021) learned that through the redesign of their Calculus corequisite, students developed critical thinking skills, developed a productive disposition towards mathematics, and began to feel more integrated into the mathematics community. Thus, these studies demonstrate that students may see an overall benefit to enrolling in a corequisite course.

The Design of a Corequisite

The corequisite model has taken on different flavors at different institutions. For instance, some institutions allow students to opt-into corequisite enrollment (Park et al., 2018), whereas other institutions mandate enrollment based on multiple measures (e.g., enrollment history and grades) (Bracco et al., 2019). Differences also occur in terms of the structure of the corequisite support. Some institutions embed academic support material with course material for seamless integration, while others separate the corequisite support material from the main content course material (Daugherty et al., 2018). In instances of the latter situation, some institutions may provide students with academic support through customized web-based modules while others may provide the support via a workshop where students receive targeted support. Another difference that can occur across different implementations of the corequisite model is in terms of the class make-up. Some institutions take a cohort approach to corequisites where students identified as needing additional support are isolated from their peers and take a different course with a corequisite support component (Richardson & Dorsey, 2019). The alternate to this approach is a comingled approach where all students take the same gateway mathematics content course and those identified as needing additional academic support are enrolled in a separate corequisite support course.

Despite these various flavors of the corequisite model, there has been insufficient research on which flavor provides students with the most optimal learning experience, in terms of course outcomes and the overall student experience. However, there has been some movement in the community in highlighting some best practices for corequisite deployment (Hancock et al., 2021; Richardson, 2021; Richardson & Dorsey, 2019). By exploring student narratives, this study adds to the movement by exemplifying how the corequisite classroom climate can positively impact students' attitudes toward learning mathematics.

Context

The data from this study was collected at Grizzly State University (GSU), a pseudonym, which is a large public four-year Hispanic Serving Institution located in the southwestern region of the United States. GSU's student body is diverse, with about 56.6% identifying as women and 57.4% identifying as students of color (e.g., 31.5% Latinx, 4.4% Black, and 0.4% Indigenous). GSU underwent major changes in its course offerings and curriculum in response to an educational reform movement within the university system to increase student retention and degree completion. The College Algebra corequisite course at GSU was developed during this reform movement with the intention of reducing the need for developmental education course offerings (i.e., pre-collegiate course offerings) and providing more access to gateway mathematics courses. Prior to the reform, GSU did not offer any developmental courses, thus STEM intending students who were not considered "college-ready" had to take their developmental courses at local two-year colleges. However, with the changes from the reform, those STEM-intending students who would typically enroll in a developmental course at the local two-year college before starting at GSU, now had access to College Algebra with a corequisite support at GSU. More specifically, GSU auto-enrolled pre-identified students (based on multiple measures including high school grade-point-averages, scores on standardized tests, etc.) into the corequisite support course when they registered for the College Algebra course.

The College Algebra course at GSU covered topics such as simplifying algebraic expressions, solving equations and inequalities, graphing and identifying key features of graphs of functions (including domain, range, and end behavior), and constructing and interpreting elementary linear and quadratics models. In comparison, the goal of the corequisite support course was to provide students with additional time to learn and work on the College Algebra course material, receive just-in-time remediation of prerequisite material, as well as develop good study habits for mathematics and other future STEM courses. GSU took a comingled approach to corequisites where all students were enrolled in any section (class) of the College Algebra course, and the students that were identified as needing additional support were enrolled in an additional course, a one-unit corequisite support course. Since both the College Algebra course and corequisite course met three times a week for 50 min each, students enrolled in the corequisite course received about five hours of mathematics instruction per week as opposed to just the 2.5 h the non-corequisite students would take.

Theoretical Framing

The sociocultural theory of learning is the overarching theoretical basis for the work presented in this manuscript. This theory focuses on the relationships between people, contexts, actions, meanings, communities, and cultural histories (Robbins, 2005). One central argument in sociocultural theory is that all learning is social (Walshaw, 2016). The unit of analysis is not merely the student but the student within their learning environment (Esmonde, 2017). In his writings, Vygotsky highlighted the dynamic interdependence between social and individual processes in cognitive development (John-Steiner & Mahn, 1996). He suggested that learning begins interpersonally (socially) and then evolves to the intrapersonal (mental) level (Confrey, 1995; Culligan, 2013). Hence, students learn by depending on their instructor and peers with more experience before participating in the environment (John-Steiner & Mahn, 1996).

Through participation within the learning environment students develop strategies, learn cultural meanings, acquire language, form relationships, and construct their identities within the community (Walshaw, 2016). Voigt et al. (2019) stated in their work on course variations of the Calculus sequence (including variations with corequisites), that "student persistence in STEM is a dynamic relationship between the opportunities for socially connecting with peers while at the same time developing strong academic ties that function as supports" (p. 3). While various other studies have shown that corequisite courses can positively impact academic outcomes in terms of grades, there is a dearth of research on the connection between how students engage in the corequisite classroom (namely, the *classroom climate*) and the impact on the student in terms of *attitudes toward mathematics*. This study explores the relationship between the corequisite classroom climate and students' attitudes toward mathematics.

Classroom Climate

It has been shown in the primary and secondary education literature that the classroom climate has a mediating role in students' academic, behavioral, and socioemotional outcomes (Wang et al., 2020). As outlined in Table 1 and elaborated by Wang et al. (2020) in their meta-analysis, *classroom climate* is a multidimensional construct consisting of three dimensions; *Instructional support, Socioemotional*

Table 1 Theoretical constructs

Construct	Dimensions	Definition
Classroom Climate	Instructional support	Instructor provides scaffolding and feedback, promotes critical thinking, and sets high expectations
	Socioemotional support	Instructor fosters an environment that support students’ emotional wellbeing
	Classroom organization and management	Instructor establishes classroom norms, maintain student engagement, and preserve order
Attitudes toward Mathematics	Beliefs	One’s subjective conceptions about mathematics and mathematics learning, their selves relative to mathematics
	Emotions (including interest)	Natural and instinctive feelings one may experience in response to a stimulus
	Behavioral response	How one engages (or avoids) mathematics

support, and *Classroom organization and management*. The classroom climate structure attends specifically to instructional practices that the instructor does to foster a particular environment. Namely, the instructional support dimension refers to instructional techniques for academic scaffolding, providing student feedback, and setting high academic standards. The socioemotional support dimension pertains to fostering a classroom environment that attends to the emotional welfare of students, including warmth, safety, connectedness, and sense of belonging. And the classroom organization and management dimension refers to the use of classroom practices for establishing classroom norms, maintaining student engagement in activities, and preserving order.

In the primary and secondary education literature, the classroom organization and management dimension of classroom climate oftentimes is associated with preventing disruptive behaviors. However, in this manuscript the classroom organization and management dimension considers the reality of postsecondary education (including instructional pivots in response to the global coronavirus pandemic), and the ways that the instructor maximizes structure in their classroom (Simonsen et al., 2008). This means that in order to maximize the structure of their classroom, an instructor may design their course to include learning both in and outside of the classroom (e.g., virtual learning, flipped classroom).

Attitudes Toward Mathematics

Many researchers study students' *attitudes toward mathematics* because this construct is widely recognized as an important factor for learning and mathematical achievement (Julian, 2017; Ma & Kishor, 1997; Majeed et al., 2013; Moenikia & Zahed-Babelan, 2010; Neale, 1969). Also outlined in Table 1 is the attitudes toward mathematics construct, which is defined by the *emotions* students have regarding mathematics, their *beliefs* about mathematics, and their *behavioral response* in mathematical settings (Hart, 1989). The construct of emotions refers to the natural and instinctive feelings one may experience in response to a stimulus (Hart, 1989; McLeod, 1988). Beliefs on the other hand refer to one's subjective conceptions about mathematics and mathematics learning, their selves relative to mathematics (including self-efficacy), and the social and socio-mathematical norms within the mathematics classroom (Op't Eynde et al., 2003). And behavioral response is how one engages (or avoids) mathematics (Hart, 1989). Additionally and consistent with Hodges and Kim (2013), motivational factors such as *interest* and *efficacy* (which is composed within the *beliefs* construct) are also considered in this manuscript as elements of a student's attitudes toward mathematics. Efficacy beliefs are the basis for action (i.e., behavioral response) and these beliefs guide students' action or inaction (Bandura, 1997). Similarly, *interest* is reciprocally related to *emotions*, as one's interest (or lack thereof) will inevitably impact their feelings about mathematics and vice versa (Hodges & Kim, 2013).

The underlying hypothesis of this study is that corequisite courses designed with a classroom climate that provides students with extra opportunities to learn course material in a supportive community can positively impact students' attitudes toward mathematics. Various studies have employed quantitative methods to measure the impact of an academic intervention on students' attitudes towards mathematics. For instance, Sanchal and Sharma (2017) demonstrated that the incorporation of a sporting context to the learning environment led to more positive attitudes toward mathematics. Other researchers concluded that project-based coursework (e.g., Julian, 2017; Selçuk, 2010), and active learning (e.g., Armbruster et al., 2009; Demirci, 2017) can have an ameliorating effect on students' attitudes toward mathematics. Logue et al. (2016) found that when students consistently attended a support workshop (i.e., a corequisite course), there was an increase in positive attitudes toward mathematics. Thus, through quantitative analyses we can see that the introduction of new learning contexts can help foster productive attitudes toward mathematics among students. This present study adds to the literature by leveraging the student voice to qualitatively learn about how students perceive the academic support offered within a corequisite course and the extent to which their attitudes toward mathematics are shifted through engagement in the course. The research question that motivates this investigation of one university's implementation of the corequisite model is, how does the classroom climate within a College Algebra corequisite course impact students' attitudes toward mathematics?

Methodology

This study is part of a larger exploration around the institutional change in developing the corequisite course at the institution of study. The larger study was conducted using a convergent mixed methods approach where quantitative and qualitative data were concurrently collected and analyzed (Creswell, 2012). These data were collected and analyzed in accordance with the guidelines and approval of the institution's Institutional Review Board. All names used in this manuscript are pseudonyms. In this section, the data sources and analytic methods are described.

Data Sources

Data collection occurred virtually during the Fall 2020 semester, a semester when GSU reported a record low number in student enrollment: presumably an effect of the global coronavirus pandemic. Accordingly, there were less students than usual registered for their College Algebra course as well as the corequisite support course. Hence, there was only one section of the corequisite course offered during this semester. There were three types of data collected during data collection for the larger study including institutional data, student interviews, and artifacts from classroom observations. For this study, we analyze only the student interview data and use classroom artifacts from observations that will help in illustrating the context of the corequisite course at the institution. For the sake of clarity and consistency in this manuscript, the College Algebra course sections will be henceforth referred to as *content sections* of the College Algebra course and the corequisite course will be referred to as the *support course* for the College Algebra course.

Student Interviews

All students enrolled in the support course during the Fall 2020 semester were solicited to participate in a semi-structured interview about their experience in both their content and support courses. Seven students, all STEM-intending majors, agreed to participate and afterwards were compensated for their time with at $20 Amazon gift card. Of the students interviewed, five identified as women, and two identified as men. They were given the pseudonyms: Adriana, Amanda, Chih-Wei, Gloria, Isbelia, Jeffrey, and Rachel. In these interviews, students discussed their lived experiences in both the content and support course, the relationships they developed with their instructor and peers, and the effect the course had on their perceptions of mathematical ability. The interview protocol is included in Appendix A.

Classroom Observations

GSU's comingled approach to corequisites meant that the students enrolled in the support course were simultaneously enrolled in different content sections. Thus, to fully capture the corequisite student experience in both their content and support courses, it was pertinent that multiple content sections were observed. There were eight content sections of the College Algebra course offered during the Fall 2020 semester, and one section of the support course. Four of the content sections, as well as the single support course were observed during the fourth, eighth, and twelfth week of the semester – for reference, there are about 16 weeks of instruction within GSU's semesters. Classroom observations were recorded using the Zoom videoconferencing platform, over six days. There was a total of 18 observations, where the support course was observed six times and the content sections were observed 12 times (with more details in Table 2). The observations were structured in a way that would mirror a typical day for a corequisite student. For example, corequisite students would begin their day with their 9am support course followed by their content section scheduled later in the day. Thus, on any given observation day, the support course would be observed at 9am, and then two sections of the content course would be observed immediately afterwards.

Table 2 Relevant details of each observed course

Course	Number of Observations	Enrollment	Make-up of Class	
			Corequisite students	Lecture-only students
Support course	6 observations	24	24	0
Content Section A1	2 observations	42	4	38
Content Section A2	2 observations	49	4	45
Content Section B	4 observations	33	4	29
Content Section C	4 observations	47	1	46

Content sections A1 and A2 were taught by the same instructor

Various classroom artifacts were collected during the observation period including the instructor's guided notes (see example in Appendix C), student work on Google JamBoards and Google Docs, researcher field notes, and corequisite student journal reflections. The corequisite student journal reflections were collected during the ninth and 16th week of the semester via a class assignment on Google Forms. Of the 24 students enrolled in the support course, 21 submitted a reflection during Week 9, and 19 submitted during a reflection during Week 16. The reflection assignment was a metacognitive activity where students were prompted to reflect on their quiz preparation, their quiz performance, and to discuss plans for improving their performance in a future assessment. In addition, students were asked to make predictions of their final course grade and to identify elements of the support course that had been beneficial for their learning (see Appendix B).

Data Analysis

The previously described data sources were used together to understand the student experience while enrolled in both the support and content course and to characterize the overall impact of the course on their attitudes toward mathematics. The analysis commenced with first cycle coding of the seven corequisite student interviews using structural codes related to the stated research question (Saldana, 2021). In particular, the interview protocol (Appendix A) was partitioned into two major parts: The Student Experience, and The Attitudes of the Student. Thus, two broad structural codes, *Student Experience* and *Student Attitude*, were used to index the data. The Student Experience code included all data that referred to students' decision to enroll in the content and support course, information about the nature of the academic support provided in the support course, and their perceptions and recollections of the content and support course. The Student Attitudes code included responses related to students' interests, beliefs, and attitudes toward mathematics and mathematics learning before and after enrollment in the support course.

After parsing all seven corequisite student interviews, a set of provisional codes were constructed based on the developmental education and corequisite literature, as well as the theoretical framework of this study (Saldana, 2021). However, these codes appeared to be too broad upon testing them on the interview data. Subsequently upon revisiting the data, a more precise list of theory-driven codes was constructed to capture the student experience relative to the classroom climate and their attitudes toward mathematics as showcased in Table 3. The final set of codes related to the Student Experience structural code included the three dimensions of the classroom climate construct as described earlier: Classroom organization and management, Instructional support, and Socioemotional support. The final set of codes related to the Student Attitudes structural code included Behavioral Response, Beliefs, Emotions and Interest, and No Effect (declared absence of a change in attitudes), aligning with the Attitudes toward Mathematics construct.

Table 3 Codes for analysis

Structural Codes	Provisional Codes	Final Codes
Student Experience	Classroom Structure Participation	Classroom Organization and Management
		Instructional Support
		Socioemotional Support
Student Attitudes	Attitudes	Behavioral Response
		Beliefs
		Emotions and Interest
		No Effect

Findings

Though the intention of this manuscript is to highlight the impact of a corequisite course beyond traditional metrics like course grades, it is worth mentioning that 15 of the 24 students enrolled in the support course passed their College Algebra content course with a grade of 75% or higher, whereas only three corequisite students were unsuccessful at passing the content course (scored below 60%). The findings are presented in two sections corresponding to student narratives around the classroom climate of the support course, followed by reflections on its impact on their attitudes towards mathematics.

The Climate of the Support Course

The three dimensions that constitute the classroom climate construct though interconnected, have their own unique characteristics as defined earlier. Student narratives about each of these dimensions are illustrated in this section.

Instructional Support

Throughout the data set, there were several instances of students questioning their auto-enrollment into the support course given their self-described proficiency in the content material for College Algebra. Even so, many of these students highlighted some benefits of enrolling in the course. One such student, Emmanuel (not interviewed) shared in his Week 16 journal reflection that the most effective aspect of the support course was simply “taking notes and showing up to class.” All corequisite interviewees, but one (Adriana), identified the academic scaffolding received in the support course as an advantage that prepared them for their content section. Jeffrey elaborated,

> So, it’s like I get like a preview of it in the morning and then whenever we’re discussing again in the afternoon it’s like oh yeah that makes sense. You know, I feel like, I am more prepared because it’s not like I’m going in like, I have no idea what we’re talking about.

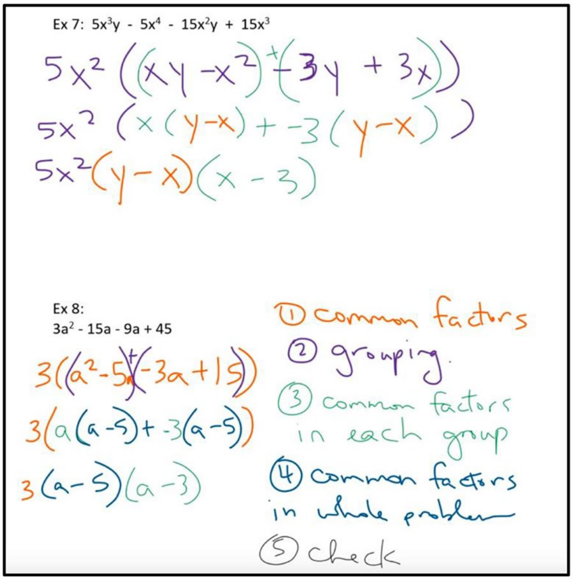
The instructor, Ms. Addison, scaffolded their learning of content material by getting students acquainted with the core language and ideas that they would encounter later in the day in their content course.

The topic covered on the second day of observation of the support and content course was *Factoring polynomial expressions*. The content instructor used guided class notes (see Appendix C) to present material around factoring techniques such as the strategy of *Factoring by grouping* (a factoring method where a common factor exists across groupings of polynomial terms). The students followed along as the instructor worked through several examples, pausing occasionally to prompt students on the subsequent step or to solicit an answer to the equation (see Fig. 1).

Prior to attending their content section on this observation day, the corequisite students spent their time in the support course reviewing *Factoring*. Ms. Addison shared a link with the students to an online scaffolding worksheet, as seen in Fig. 2, where students were asked to plan their work before attempting to factor each polynomial. Students were first prompted to identify distinguishing features of the polynomial, then outline how they would factor the polynomial based on the features, and finally execute the steps towards factoring the polynomial. Ms. Addison gave the students five minutes to work independently on the factoring activity before putting them into Zoom breakout rooms to collaborate on the activity with their peers. At the end of class, Ms. Addison instructed students to independently reflect on the activity by completing a Likert scale on the second page of the worksheet to rate their success in factoring each of the four presented polynomials (see bottom half of Fig. 2).

These type of classroom sequences persisted throughout the observation period. The students in the content course would follow along with the instructor as they presented new content with examples via guided notes. The students in the support course would engage in either a discussion around previous content (including

Fig. 1 Guided notes from Day 2 of content section observation



Ex 7: $5x^3y - 5x^4 - 15x^2y + 15x^3$

$5x^2((xy - x^2)\,{}^{+}(-3y + 3x))$

$5x^2(x(y - x) + -3(y - x))$

$5x^2(y - x)(x - 3)$

Ex 8:

$3a^2 - 15a - 9a + 45$

$3((a^2 - 5a)\,{}^{+}(-3a + 15))$

$3(a(a - 5) + -3(a - 5))$

$3(a - 5)(a - 3)$

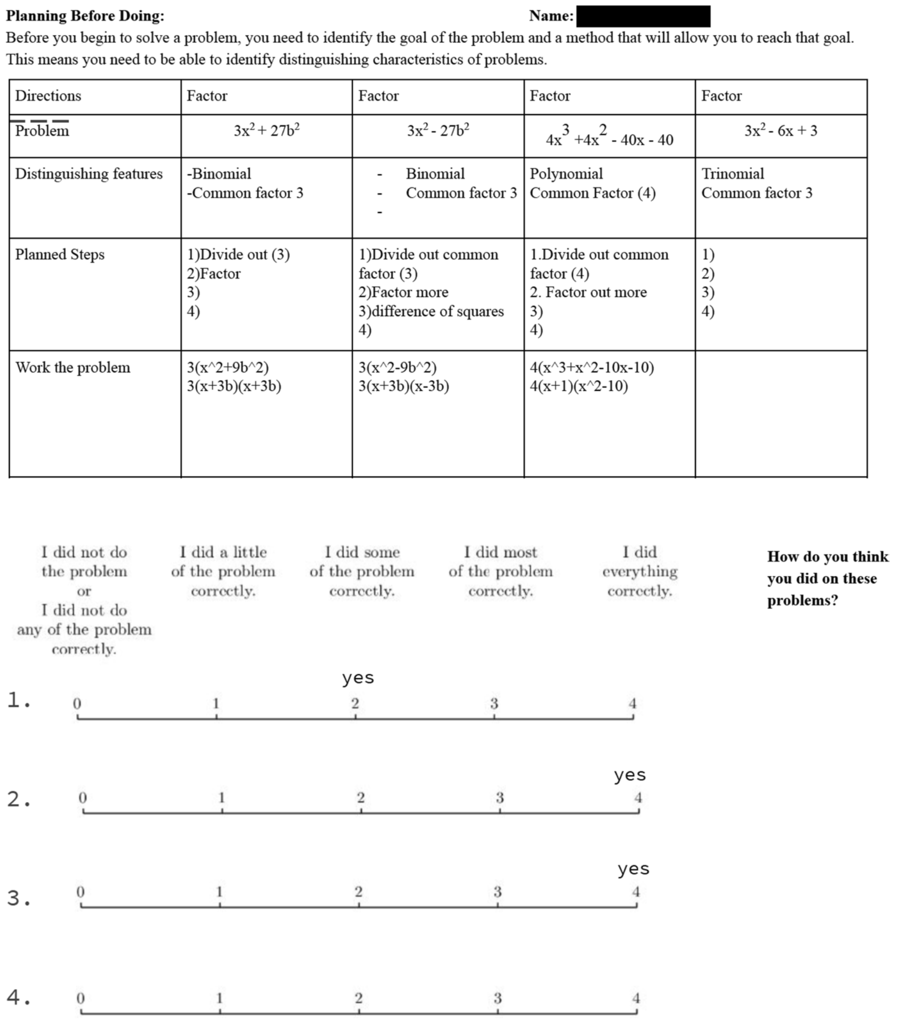
① common factors

② grouping

③ common factors in each group

④ common factors in whole problem

⑤ check



Planning Before Doing: **Name:** [redacted]

Before you begin to solve a problem, you need to identify the goal of the problem and a method that will allow you to reach that goal. This means you need to be able to identify distinguishing characteristics of problems.

Directions	Factor	Factor	Factor	Factor
Problem	$3x^2 + 27b^2$	$3x^2 - 27b^2$	$4x^3 + 4x^2 - 40x - 40$	$3x^2 - 6x + 3$
Distinguishing features	-Binomial -Common factor 3	- Binomial - Common factor 3 -	Polynomial Common Factor (4)	Trinomial Common factor 3
Planned Steps	1)Divide out (3) 2)Factor 3) 4)	1)Divide out common factor (3) 2)Factor more 3)difference of squares 4)	1.Divide out common factor (4) 2. Factor out more 3) 4)	1) 2) 3) 4)
Work the problem	3(x^2+9b^2) 3(x+3b)(x+3b)	3(x^2-9b^2) 3(x+3b)(x-3b)	4(x^3+x^2-10x-10) 4(x+1)(x^2-10)	

0	1	2	3	4
I did not do the problem or I did not do any of the problem correctly.	I did a little of the problem correctly.	I did some of the problem correctly.	I did most of the problem correctly.	I did everything correctly.

How do you think you did on these problems?

1\. 0 1 2 3 4 — yes (2)

2\. 0 1 2 3 4 — yes (4)

3\. 0 1 2 3 4 — yes (4)

4\. 0 1 2 3 4

Fig. 2 Student work from factoring activity from Day 2 of support course observation

assessments), preview new content through interactive scaffolding activities such as online worksheets and/or online puzzles and mazes, or engage in metacognitive group activities such as learning how to take notes in a mathematics class and critical thinking activities that encouraged students to plan their mathematical activity when presented with novel problems.

Ms. Addison also provided students with instructional support in the form of opportunities for receiving feedback on their progress through assigning additional home practice problems. Chih-Wei shared,

> I really think the [support] class helped me a lot because it's just like an extra class that assigns you like more homework, like the one of those that's optional for [the content class]. I think it's pretty helpful when you actually do it.

Optional assignments in the content course were required assignments for the corequisite students, and students like Chih-Wei found great benefit in the external motivation to complete the assignments. However, these opportunities for instructor feedback were perceived as time-consuming to other students. In the Week 9 reflections, Jasmine (not interviewed) addressed the time-consuming nature of the work as something that has not been effective for her learning during the semester. She complained that "assigning four homework assignments for one class when [she has] so much other stuff to do for other classes and [the content course]" as something that was not working well.

Classroom Organization and Management

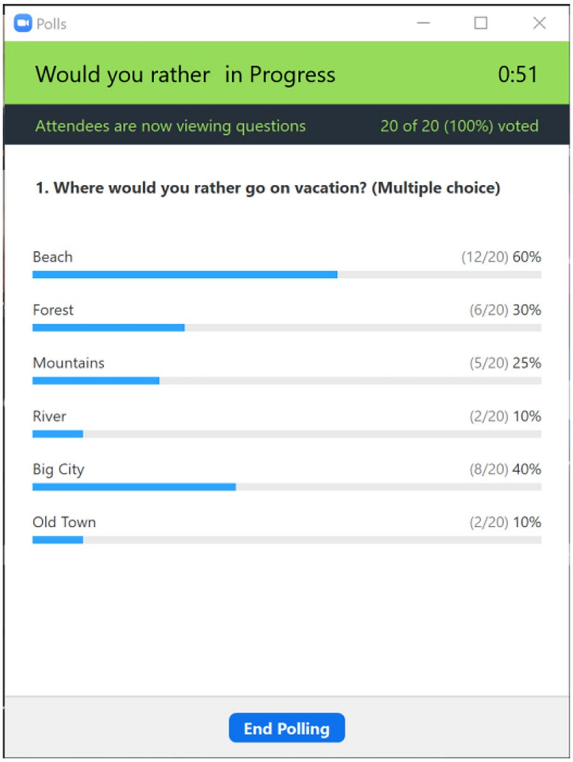
Gloria summarized the difference between the content course and the support course by stating, "I think [the support course] is more for problems that you have questions with and [the content course] is just so you absorb everything from the lecture." The difference between the courses was evident from the very start of each class. While the content instructors would begin class promptly by directing students to their guided notes, Ms. Addison began the support course with an ice breaker activity (sometimes related to mathematics and other times related to students' personal lives). For instance, on the third day of observation Ms. Addison posted a Zoom poll asking students about their ideal vacation (see Fig. 3). This classroom norm diverted students' attention away from other distractions and encouraged students to informally engage in classroom dialogue before transitioning into the mathematics learning of the day.

Ms. Addison primarily engaged students in the content through whole-class or group activities. On average, the corequisite students spent more time engaging in groupwork in the support course (around 37% of class time ~ 18.5 min) than in their content course (16% of class time ~ 7.8 min). As a result, the students in the support course vocally participated more often than the students in the content sections. Vocal participation here refers to students unmuting themselves and contributing to the classroom discussion. In fact, 19 of the 24 corequisite students vocally participated during the observation period.

Though Ms. Addison established a classroom norm for groupwork, it was not always productive. When asked to reflect on what has not been effective in the corequisite in their Week 9 reflection survey, Fernando (not interviewed) simply stated "breakout rooms." Three of the interviewed students also mentioned the breakout rooms as a source of negative interactions in the support course. Amanda shared about her peers,

> I usually ask them 'can you double check my work?' … And they would double check it and then they tell me what they think it is. And it's a little hard

Fig. 3 Support course ice breaker on Day 3 of observation



Would you rather in Progress 0:51

Attendees are now viewing questions 20 of 20 (100%) voted

1. Where would you rather go on vacation? (Multiple choice)

Beach	(12/20) 60%
Forest	(6/20) 30%
Mountains	(5/20) 25%
River	(2/20) 10%
Big City	(8/20) 40%
Old Town	(2/20) 10%

> when they try explaining it to me though. Because … I don't fully understand fully about their work and everything.

While working in groups did provide opportunities to learn from peers, it also led to instances of communication breakdowns and unproductive collaboration like this one. Whenever Amanda's groupmates attempted to help her understand her errors, she would get confused with their reasoning – often these moments of miscommunication were not resolved during the class period. Isbelia shared that groupwork was beneficial primarily when she needed help. She added, "but if I do understand the material, I like working by myself because I feel like I get more done." Jeffrey's complaint about groupwork was related to the overall division of labor while working on class assignments in the breakout groups.

> There was one instance where I was in a breakout room, and it was like nobody did anything but me. So, it was like I did all the work. And I was like, trying to get other people involved, like, 'Hey, do you guys know what to do here?' And like one of the people responded 'No, I don't.' And then it is just like the other two, they just didn't do anything.

During times like these, Ms. Addison was not able to maintain student engagement for all students through groupwork, in part because students may not have been ready (in terms of conceptual knowledge) to engage in groupwork on the topic of the day. In this instance, Jeffrey was the only person prepared to engage with the activity in his group of four. Jeffrey later clarified, "but yeah, it was just that one instance."

Socioemotional Support

The support course was the first mathematics course of the day for all the corequisite students. And as described earlier, Ms. Addison began each class with an icebreaker to set a positive tone for the day. Gloria contrasted her experience in the support course with Ms. Addison to her experience with their content instructor by stating,

> I feel like for [the content course], it's more like okay, you're here to like lecture, lecture, lecture. And then … like Ms. Addison gives like a better … I don't know, like her vibes and her way of teaching is a little bit more peppy.

The warmth that exuded from Ms. Addison's "peppy" personality set a contrasting tone for the support course relative to the content course. This difference in environment may have influenced students' help-seeking behaviors where some students chose to attend Ms. Addison's office hours over their content instructors whenever they needed additional help. For instance, Adriana described,

> I would, for sure attend [Ms. Addison's] office hours, just because I felt a lot more relaxed and comfortable with her just because she knew that she was there to help us with the [content] class, so I was just more comfortable going to her to ask for help.

Ms. Addison created an environment where students felt safe and comfortable in seeking additional support outside of the content and support course. Adriana perceived Ms. Addison as someone specifically positioned to help her, thus if she needed additional support on course content and was deciding which instructor's office hours to attend, she would gravitate to Ms. Addison's office hours over those of her content instructor.

When the corequisite interviewees were explicitly asked about their perceptions of the classroom climate in the support course, they characterized an environment of safety, connectedness, and a culture of inclusion. Specifically, they used adjectives such as "positive, "open," and "chill." Amanda responded, "I would say [the climate] is pretty good. Everyone seems almost positive, people are a little tired, but pretty positive." Jeffrey explained, "I think that … the environment in the classroom is not as like being judged or somebody is better than somebody, you know … It's just feels like an open environment." He described the classroom environment as a place where he felt open to contribute and unafraid to make mistakes. Chih-Wei characterized the classroom climate as "chill" stating, "you can just talk to people after you're finished stuff like, … it was really helpful since we're all virtual now and then you can really get in touch with people." This opportunity to build community was important for him given the virtual nature of the classroom, especially since he was geographically located in another country during the time of data collection and had few opportunities to meet and collaborate with peers.

The social norm of collaboration was established in the corequisite course where the feeling of safety, community, and mutual support was mentioned by all the corequisite interviewees. Adriana stated,

> I think about the [support] course, I really liked how overall how helpful everyone was. So, like they understood that not everyone is the best with math, and you know, like everyone learns differently, especially online. So, everyone was really understanding and … just flexible overall because they know like not everyone is in the same position, you know, so I really like that.

Through collaboration in breakout rooms, students were able to support each other in the virtual space. As Adriana and Jeffrey put it, there was minimal judgement and mutual recognition of the diversity of understanding within the class.

Attitudes toward Mathematics given the Support Climate

The corequisite students entered the support course with a variety of life experiences that impacted their orientations towards mathematics and how they perceived themselves within the mathematics community. Five of the seven corequisite students interviewed (Isbelia, Amanda, Adriana, Chih-Wei, and Jeffrey) stated that they historically were not good at math. Six of them (all but Gloria) stated that they had negative experiences learning mathematics in the past. In this section, student narratives about the impact of the climate of the support course on their attitudes toward mathematics are presented.

No Effect

There were mixed responses when the corequisite students were explicitly asked about the personal impact of the support course. For some, including Rachel and Adriana, the support course did not have any effect on their attitudes toward mathematics. Though Rachel did not provide any further elaboration on her response, Adriana shared,

> Honestly, it didn’t really affect like my interest in math at all, its kind of just remained the same. I was like I know I’m not the worst at math, but I definitely could … improve in it. So, I don’t know, its kind of just stayed the same, for me, honestly.

She clarified that these responses were not a criticism of her instructor, but rather it is about her own personality. Her relationship with mathematics was unchanged by the support course.

Behavioral Response

Though Adriana reported no changes in her attitudes toward mathematics, she did report a general behavioral shift which by definition is a shift in attitude in response to the experience. Specifically, Adriana shared,

> From the [support] course I think I was able to like, just kind of be more organized with my work. Just because I knew I would have a lot coming for this week, and not just from those two classes. So, I was like … Okay, I need to get this done before this day ... And yeah, that was honestly like the biggest thing that really did it for me like it just made me a lot more organized with my work.

Adriana's biggest complaint about the support course was that it was time-consuming. However, the classroom norms and expectations for engagement in the support course led to a behavioral shift in how Adriana approached and managed her studies. However, this behavioral shift was not unique to how she engaged in mathematics, but rather how she approached her education that semester at GSU.

Amanda, on the other hand, reported becoming more organized stating, "[the support course] tells me what I am doing … what I'm going to do and what I need to do." Considering the academic scaffolding and classroom expectations set by Ms. Addison, Amanda restructured her workload to better attend to her learning of College Algebra content material.

Beliefs

Students reported changes in beliefs about their mathematical capabilities in response to the support climate. The experience in the support course led to overall positive efficacy beliefs for some students, and an increase in confidence in participating in mathematics for others. Gloria linked her newfound confidence to her projected course grade where she stated, "since I have like a good grade in [the content course], it's like making me think, oh, I am actually good at math." Isbelia had a negative relationship with mathematics prior to enrolling into the support course, and she developed anxiety around the course after recognizing that mathematics (especially this course) was her primary obstacle in pursuing a biology major. She shared,

> I know with science, I always knew I wanted to do something in science, but I also knew science also relates with math. So that kind of like put me down. And I was like, I suck at math. And like I just, I won't be able to go the science route, but I finally understand. Again, I'm like, Okay, yes, this is what I want to do, like, I'm very happy with it. Like I don't dread math anymore. Like I come in. I'm like, okay, like I know what I'm doing. Like I can get all my work done on time.

The support course had a significant impact on students like Isbelia, who had an aversion to learning and doing mathematics. The instructional and socioemotional support that was provided in the support course made an impact on her attitudes towards mathematics. After completing the course, she reported feeling more confident in her algebra skills. Isbelia also endorsed Ms. Addison as the best instructor she has ever had stating, "I ask her questions, and she answers it. Unlike my other math teachers, where I would ask a question on how they got an answer and they just be like, I don't know … you tell me." Isbelia felt safe asking questions and engaging in the support course, and eventually the content course as well. Isbelia shared,

> I don't like talking in class because I have a fear of it, but [Ms. Addison] makes me feel comfortable because like I said she doesn't put me down, make me feel stupid like my other teachers have made me feel stupid.

Amanda explained that in addition to her increased confidence in her mathematical abilities, she also was more comfortable participating. She shared, "[the support course] is getting me to be more confident as I was having a hard time before. But I am more willing to talk more and explain why I got my answers." As a result of the classroom norms set for student collaboration in whole-class and Zoom breakout rooms, students spent a significant portion of class time co-constructing their understanding of content material and interacting in online activities. The ability to communicate one's reasoning was a critical skill that students needed to develop to fully engage within the community. As described earlier, Amanda reported some initial negative experiences in group communication during these collaborative learning opportunities. However, by the 10th week of the semester, she reported feeling more confident communicating with her groupmates and felt more comfortable advocating for herself and interacting with her peers due to the safe environment facilitated by Ms. Addison.

Emotions and Interest

Lastly, several students (Isbelia, Chih-Wei, Amanda, and Jeffrey) demonstrated a shift in their emotional orientation towards mathematics and expressed a greater interest in doing and learning mathematics as a result of the support course. Chih-Wei and Jeffrey described feeling a sense of euphoria when solving problems after understanding the concept. Chih-Wei stated, "once you solve more, you're like … hey I know this, I can do good." Similarly, Jeffrey explained, "it's like, and I kind of can't wait to do some of this work because I understand it now." The academic scaffolding and overall classroom climate of the support course encouraged a behavioral shift in how Jeffrey engaged with the mathematics he was learning.

Being able to understand the material and demonstrating mastery in the material directly affected these students' sense of efficacy (Bandura, 1997), and overall interest in doing the mathematics. Isbelia shared,

> I feel like I have gained so much knowledge in math and I am so proud of myself. I have never been proud of myself in math. So, I'm really glad that I'm

> passing this class right now and the professor has been a big help. The [corequisite] support has been such a big help as well.

The experience in the support course pushed many students, like Isbelia, to reconsider their relationship with mathematics. Isbelia now thinks positively about her potential for understanding mathematics as she continues forward along her STEM pathway. This sentiment was echoed by Amanda who described how her beliefs shifted in response to the support course:

> [The support course is] getting me to like math more because I didn't really like math … Because like it's getting easier for me. Before it was so hard. Now, it's slightly easier and I'm pretty sure it will get easier as more time goes by.

Discussion

This study examined one university's deployment of the corequisite model in their College Algebra course in order to answer the research question, how does the classroom climate within a College Algebra corequisite course impact students' attitudes toward mathematics? Even though two students stated that the support course had no effect on their attitudes toward mathematics, only one of them truly demonstrated a lack of change in attitudes in response to the climate of the support course (Rachel). As summarized in Table 4, the multiple dimensions of classroom climate did influence shifts in the participants' attitudes toward mathematics in various ways. Instructional support was the climate dimension that was reported to impact all aspects of attitude shifts. Namely, the instructional practices for setting high expectations, scaffolding student learning of content material, and providing

Table 4 How classroom climate impacted attitudes toward mathematics

Attitudes toward Mathematics	Classroom Climate Factors
Behavioral Response	Instructional support – The academic scaffolding and modeling helped students to structure how they approach engaging in the College Algebra coursework. In addition, the high expectations for engagement outside the classroom set by the instructor incentivized students to plan ahead and be more intentional in their time management
Beliefs	Instructional support – The instructor was responsive to student questions and provided feedback without judgement, allowing students to feel more confident participating within the classroom
	Classroom organization and management – The established classroom norms for collaborative learning helped students become more comfortable participating in the mathematics community
	Socioemotional support – The instructor made students feel comfortable and safe to ask questions and overall engage within the classroom
Emotions (& Interest)	Instructional support – The academic scaffolding helped student better understand and experience success in engaging in mathematical activity in the content course

feedback facilitated student learning and understanding of core content material, as well as better executive functioning (time-management and organization).

Students discussed at length how positive the classroom climate was (e.g., “chill”), and how Ms. Addison’s “peppy” personality made them feel comfortable engaging in the whole class and in group activities. However, the socioemotional support dimension explicitly appeared only in student narratives around their shifts in beliefs about selves relative to mathematics. In other words, this aspect of the classroom climate did not specifically affect other aspects of the participants’ attitudes toward mathematics. Even so, Ms. Addison’s instructional practices for supporting students’ emotional wellbeing had a profound effect on several students, especially Isbelia.

According to the students in this study, the classroom organization and management dimension was only explicitly connected to shifts in beliefs. Though students valued the icebreakers and opportunities to collaborate with their peers, no one explicitly cited these classroom norms as factors for their change in perceptions. However, these aspects of the learning environment were generally important for fostering a culture of inclusion and connectedness which helped initially reluctant students gradually become more comfortable participating in the learning environment.

Finally, there was evidence that all three dimensions of the classroom climate construct impacted the participants’ beliefs about mathematics and their ability to learn and do mathematics. This conclusion is consistent with the literature from the primary and secondary education context, where Wang et al. (2020) determined that there are positive associations between classroom climate and student social competence, motivation, and academic outcomes. From the student narratives, we see that even in postsecondary learning environments, an intentional focus on promoting positive classroom climate can help students develop productive beliefs around mathematics and position them as doers of mathematics.

Most of the students in this study reported shifts in their efficacy beliefs based on their mathematical accomplishments in the content course due to the instructional support provided in the corequisite course. Bandura characterized this source of attitudinal change as *enactive mastery experiences* where the experience of success positively affects a learner’s self-perception of ability (Bandura, 1997). Other students (e.g., Amanda and Isbelia) reported a shift in their beliefs in their ability to participate in the mathematics community due to the classroom norms and community established in the corequisite course. Lastly, the routine encouragement by Ms. Addison and other peers helped students feel more capable of success in mathematics; Bandura characterized this source of attitudinal change as *verbal persuasion* where an influential member in a community positions the student as capable (Bandura, 1997).

The primary criticism of the corequisite classroom climate was around instructional support that some students characterized as “time-consuming” and occasionally, the classroom norm of collaborative learning. The extra practice outside of the classroom was perceived as excessive considering that the corequisite students also were assigned similar homework in the content course. Regarding the issue of collaborative learning, the participants generally enjoyed group collaborations and the community they were forming within the support course. However, several students highlighted instances where the collaboration and discourse were not productive.

The student narratives about their corequisite experiences suggest a need for careful consideration in designing support coursework that encourages collaboration and community-building while also ensuring productive groupwork and discourse. Their recounts of poor group interactions are evidence of a need for greater supervision, more structure, and greater scaffolding prior to the activity to ensure that students are at a place where they can productively engage in collaborative learning. This finding confirms the conclusions of Hancock et al. (2021), where the incorporation of cognitively demanding and group-worthy tasks within corequisite courses were key to supporting students' academic development.

Limitations and Future Work

There were two primary limitations of this study, both related to the effects of the global coronavirus pandemic. First, there was a sizable decrease in student enrollment during the time of data collection, and as a result there was only one corequisite course offered that semester. As the findings demonstrate, the shift in attitudes corresponded to the classroom climate created by the instructor. As we continue to study and design corequisite courses it is necessary to consider more instructors in order to paint a holistic picture of the potential of corequisite courses for student learning.

The second limitation of the study was the small sample size of study participants. Though all 24 corequisite students were solicited for interviews, only seven agreed to participate in an interview. This study was only able to capture student reflections from more students via course assignments in which 21 of the 24 students completed. However, student responses in their journal reflection assignments were limited and there were no opportunities to ask follow-up questions. In addition, student responses in the reflection assignments may have been self-censored since they were aware that their instructor would have access to their responses.

Nevertheless, the student voices elevated from the seven student interviews were important in shining light on aspects of the corequisite student experience that has not yet been documented in research studies. Previous studies primarily relied on quantitative data in the form of surveys with Likert-type scales. By leveraging these student voices, instructors, course designers, and other institutional changemakers can be more intentional in their design of future academic support mechanisms like the corequisite model that will provide students with the most optimal experience for learning, academic growth, and fostering positive attitudes toward mathematics.

Conclusion

Corequisite courses designed to provide students with just-in-time remediation and additional academic support for learning course content have been shown to facilitate positive student academic outcomes in gateway mathematics courses. According to the students in this study, the corequisite classroom climate, which is largely facilitated by the instructional practices of the corequisite instructor, can have an impact on students' attitudes toward mathematics. This is especially true in terms of fostering productive beliefs about mathematics and about students' perceptions of themselves as learners of mathematics. These types of academic support systems are essential for students, like many of the study's participants, that have weak mathematical backgrounds and/or perceive themselves as incapable of participating in the mathematics classroom. The documented student experience in this study is a testament for course developers to consider when developing and deploying the corequisite model at their institutions.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s40753-023-00226-y.

Acknowledgements Thank you to the students for their time and willingness to share about their learning experiences.

Author's Contributions Amelia Stone-Johnstone was responsible for the conceptualization, data collection and analysis, and writing.

Availability of Data and Materials The dataset supporting the conclusions of this article is included within the article.

Declarations

Competing Interests There are no competing interests with respect to this work.

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