Prevailing Themes Across Corequisite Mathematics Courses: A Systematic Review

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Adopting corequisite mathematics models to accelerate students' completion of their introductory college-level mathematics course in their first year of college is prevalent across higher education institutions. This systematic review demonstrates the known research, evidence, and diversity of implemented corequisite mathematics models for prevailing themes across peer-reviewed articles.

Introduction

Mathematics is a challenge for many postsecondary students trying to complete college. This is especially true for students identified as academically underprepared (Mathematical Association of America, 2019; U.S. Department of Education, 2017; Saxe & Braddy, 2015). Nationally, from 2003 to 2009, 59 percent of public postsecondary students were enrolled in developmental education in mathematics (dev-ed mathematics), with a larger percentage of students enrolled in dev-ed mathematics at public two-year institutions as compared to public four-year institutions (51 and 29 percent, respectively) (U.S. Department of Education, 2017; Xianglei et al., 2016). Enrollment in dev-ed mathematics is disproportionately higher for historically marginalized student populations, including Black and Hispanic students, first-generation students, and students from low-income communities (Hodara, 2019). At public two-year institutions, 78 percent of Black and 75 percent of Hispanic students were enrolled in dev-ed mathematics, compared to 64 percent of White students (Xianglei et al., 2016). Many students enrolled in dev-ed mathematics courses do not complete the necessary course sequences nor progress to completing the required college-level mathematics coursework for their degree. Among 2003-2004 beginning two-year postsecondary students, only 50 percent completed all dev-ed mathematics course sequences, with 62 percent earning college-level mathematics credit in an undefined time frame (Xianglei et al., 2016). For hundreds of thousands of postsecondary students, dev-ed mathematics became the graveyard for their higher education aspirations and dreams.

A growing body of research has scrutinized the effectiveness of the traditional dev-ed mathematics model, which commonly places students into a series of non-credit-bearing mathematics courses. Evidence strongly suggests that the traditional dev-ed mathematics model has an ineffective structure with severe over-placement into dev-ed mathematics coursework, multiple stop-out points between coursework, limited curricular alignment to students' introductory college-level mathematics course and program of study, and high failure rates (Scott-Clayton et al., 2014; Bailey et al., 2010; Shudde & Keisler, 2019; Hern & Snell, 2014). Over recent years, improvements to dev-ed mathematics have taken many forms; one such form with resounding effectiveness is implementing the corequisite mathematics model, where students concurrently enroll in college-level and developmental mathematics coursework for just-in-time academic support (Ryu et al., 2022). Numerous national, state, and institutional studies suggest that the corequisite mathematics model eliminates exit points and improves college-level mathematics coursework completion rates (Denley, 2016; Logue et al., 2016, 2019; Meiselman & Shudde, 2021; Ran & Lin, 2019; Charles A. Dana Center, 2018a, 2018b). These positive short-term impacts of the effectiveness of the corequisite mathematics model are further legitimized by evidence of the long-term impacts. Douglas et al. (2022) examined the seven-year results of a City University of New York randomized controlled trial of the corequisite mathematics model for college-level statistics. They found that students assigned to the corequisite group were 50 percent more likely to complete their associate degree within three years and 100 percent more likely to complete a bachelor's degree within five years.

With such promising evidence, states, systems, and institutions of higher education nationwide have feverishly adopted the corequisite mathematics model to accelerate students' completion of their introductory college-level mathematics course in their first year of college. In Texas, legislators passed House Bill 2223 in 2017, which required a certain percentage of academically underprepared students to be enrolled in a corequisite support model based on their college readiness scores on the Texas Success Initiative Assessment. By fall 2021, 100 percent of a Texas public higher education institution's students enrolled in developmental mathematics had to be enrolled in a corequisite mathematics model (Texas Higher Education Coordinating Board, 2021). Similarly, Assembly Bill 705 was passed in California in 2017 to expand the use of multiple measures of student placement and maximize the probability that a student will enter and complete transfer-level coursework in English and mathematics within one year of college enrollment (California Community Colleges, 2018). California community colleges have adopted and scaled the corequisite mathematics model to maximize the likelihood of students entering and completing their transfer-level mathematics within one year of college enrollment. Fall 2019 data indicated 91 out of 114 colleges (80 percent) across the California Community College System offered the corequisite mathematics model for Statistics/Liberal Arts Math, while 84 colleges (74 percent) offered the corequisite mathematics model for STEM Math (Hern, 2019). Broad-scale adoption and ongoing evidence continue to reinforce that the corequisite mathematics model works to help accelerate students' completion of their first college-level mathematics course, yet what is less known are the structural factors of the corequisite mathematics model that garner the greatest impact on student success.

Adoption of the corequisite mathematics model is commonly based on the needs of each institution of higher education, with no single model being identified as best practice (Dana Center Mathematics Pathways, 2018). At a minimum, institutions of higher education must consider the following structural factors when designing their model: existing student success initiatives that align and support the corequisite mathematics model (e.g., guided pathways, mathematics pathways), academic readiness placement policy, timing of support, staffing, instructional modality, and class composition. The multitude of structural variations across corequisite mathematics models leaves open the possibility of an infinite number of structural factors that could impact or hinder adoption and scale. This variation mystifies higher education practitioners trying to pinpoint which structural factors most impact student access and success in introductory college-level mathematics courses.

To assist higher education practitioners, this literature review demonstrates the known research, evidence, and diversity of implemented corequisite mathematics models for prevailing themes across peer-reviewed articles. The literature review will also identify gaps in research and evidence needed to continuously improve the corequisite mathematics model.

Methods

The authors conducted this systematic review following the guidelines for conducting high-quality literature reviews described by Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Page et al., 2020). In the following sections, the authors describe their search strategy and the inclusion and exclusion criteria.

Search Strategy

Since the authors of this review are from different university systems, they chose to use research databases from one of their universities. At this university, the library had twenty-four databases identified as “education” databases and twelve identified as “mathematical sciences” databases. After excluding the databases whose descriptions indicated that they would not contain articles pertaining to corequisite courses in undergraduate education, thirteen databases comprised the search field (see Table 1).

After an initial, unsuccessful search to identify other systematic reviews on corequisite courses in undergraduate education, the authors conducted a comprehensive search of these databases in March 2022.

Table 1
University Databases Searched

Database	Education Database	Math Sciences Database
Education Source	X	
ERIC	X	
Teacher Reference Center	X	
Academic Search Complete	X	X
Chronicle of Higher Education	X	
JSTOR	X	X
PsycINFO	X	
MathSciNet		X
Science Direct		X
Springer Link		X
Oxford Journals		X
Web of Science		X
WorldCat		X

Inclusion and Exclusion Criteria

All searches were limited to peer-reviewed articles in English. Table 2 shows the search terms used, the number of articles found, the number of articles removed for various reasons, the number of new articles added to the search, and the running total of the articles.

Table 2
Inclusion and Exclusion Search Criteria for Systematic Review

Search Terms	Number of Articles Found with Duplicates Removed	Number of Articles Removed due to "Corequisite" not Appearing in Title or Abstract	Number of New, Non-Duplicate Articles	Total Number of Articles
Peer-reviewed, in English, "corequisite or co-requisite" IN TITLE and education	41			40
Peer-reviewed, in English, "corequisite or co-requisite" IN TITLE and "math" or algebra or "calculus or statistics"	29		2	42
Peer-reviewed, in English "corequisite or co-requisite" IN TITLE and "remedial" and "education"	216	167*	22	64
Peer-reviewed, in English, "just in time or just-in-time" IN TITLE and "math" or algebra or "calculus or statistics" and "education" and "corequisite or co-requisite"	4	4*	0	64
Peer-reviewed, in English, "just in time or just-in-time" IN TITLE and "math" or algebra or "calculus or statistics" and "education"	92	89**	3	67
Peer-reviewed, in English, "developmental or supplemental or labs" IN TITLE and "math" or algebra or "calculus or statistics" and "education" and "corequisite or co-requisite"	4		3	70
Peer-reviewed, in English, "developmental or supplemental or labs" IN TITLE and "math" or algebra or "calculus or statistics" and "education"	94	82*	8	78
Peer-reviewed, in English, "co-calculus" IN TITLE	1		1	79

Note. *Corequisite or Co-requisite not found in the title or abstract; **Just-in-time (JIT) math for classes other than math

After conducting a comprehensive search, the authors began reviewing each of the seventy-nine articles in more detail to determine which peer-reviewed articles would be included in the final analysis. Using a spreadsheet to track the work, the authors reviewed articles to determine:

- Subject area of the corequisite course and supported introductory mathematics course;
- Type of institution (e.g., two- or four-year);
- Study size and number of participants;
- Description of the article's definition of "corequisite"; and
- Description of the placement model used.

Based on this analysis and numerous discussions among authors, forty-six articles were removed from consideration, leaving thirty-four articles to draw from for known research, evidence, and the diversity of corequisite mathematics models to clarify which structural factors increase the effectiveness of student success. The most common reason for exclusion was that the article did not pertain to mathematics; several excluded articles focused on the corequisite model and an introductory, credit-bearing course from another content area. Other reasons for exclusion from the search included small sample sizes and descriptive overviews of corequisite course models with no empirical evidence of effectiveness.

Findings

After reviewing the thirty-four articles, several prevailing themes emerged that were used to organize the findings, including mathematics pathways, student placement, and corequisite design.

Mathematics Pathways and Corequisite Mathematics Courses

Implementing corequisite mathematics courses at higher education campuses commonly coincides with mathematics pathway reforms. Mathematics pathways reform is the intentional effort of higher educational campuses to align and enroll students in the right mathematics course for their program of study. The reform emphasizes the diversification of mathematics course content that students take to better align with their academic and career interests and how they learn (Bressoud, 2016; Gordon, 2008; Kilpatrick et al., 2001; Rutschow et al., 2019). Research directly linking mathematics pathways reform—specifically, which introductory, college-level math course was taken and how it was taught—to student success is limited. Much of the evidence surrounding mathematics pathways reform has focused on student engagement and motivation related to the relevance of mathematics content to students' programs of study and accelerating students to and through developmental mathematics coursework and their introductory college-level mathematics course aligned to students' programs of study (Rutschow & Diamond, 2015; Dadger et al., 2021; Ran & Lin, 2019; Logue et al., 2016, 2019; Meiselman & Shudde, 2021). Of the thirty-four articles examined in this literature review, the authors found that corequisite mathematics courses and mathematics pathways reform were commonly implemented together, albeit that few articles meaningfully examined both reform efforts in relation to student success.

Of those articles that did examine both corequisite mathematics and mathematics pathways reform, Ran and Lin (2022) offered significant results in their study, which provided causal evidence on the effects of a statewide corequisite reform and examined the effect of corequisite remediation by mathematics pathway. In contrast to prior studies, Ran and Lin (2022) disentangled both reform efforts to better understand their effects on student success. The authors used deidentified state administrative data for first-time-in-college students who entered one of thirteen community colleges in Tennessee between 2010-2011 and 2016-2017 (Ran & Lin, 2022). The sample population consisted of 52,036 students with ACT scores, with many students being initially excluded from the sample population due to different measures used for student placement, e.g., COMPASS, that did not align with the methodology used by the authors. As has been found across many research studies focused on corequisite remediation, Ran and Lin (2022) found that students placed in corequisite remediation were up to 18 percentage points more likely to pass their introductory, college-level math course by the end of their first year in college. Ran and Lin (2022) expanded this finding by explicitly identifying the positive effects on students completing their introductory, college-level math course through corequisite remediation that were largely driven by intentional efforts to guide students into the right mathematics course for their program of study. The effects of placement into corequisite remediation in combination with mathematics pathways were more profound for alternate pathways—such as statistics, math for liberal arts, and other math—as compared to the algebra-calculus pathway. Andrews and Tolman (2021) examined a population of 1,934 students who enrolled in at least one corequisite English or mathematics course at a community college in the southeastern United States between 2015 and 2018. Alongside examining the effectiveness of corequisite remediation on student success, the authors identified students' academic majors, which determined their access to and enrollment in aligned introductory, college-level mathematics courses. Andrews and Tolman (2021) found that students who enrolled in corequisite remediation and an appropriate mathematics course for their academic major were more likely to be academically successful.

Similarly, fourteen of thirty-four articles (41 percent) examined the effectiveness of corequisite mathematics courses within alternative mathematics pathways, such as statistics, quantitative literacy or reasoning, and other math courses. Of the fourteen articles, two specifically examined corequisite remediation effectiveness within an introductory, college-level statistics course; seven examined corequisite remediation effectiveness within an introductory, college-level quantitative literacy or quantitative reasoning course; and five examined corequisite remediation effectiveness within multiple mathematics pathways. See Table 3 below for an expanded analysis of these studies, including the year the article was published, which mathematics pathways were under examination, the location of the study, and the type of institution.

Table 3
Studies Examining the Effectiveness of Corequisite Remediation Models within Alternative Mathematics Pathways

Author(s)	Year of Article Publication	Target Mathematics Course(s)	Location of Study	Institution Type
Atkins & Beggs	2017	Quantitative Literacy	Missouri	University
Atkins & McCoy	2016	Quantitative Literacy	Missouri	University
Andrews & Tolman	2021	STEM Non-STEM	Southeastern United States	Small, Rural Community College
Beamer	2021a	Quantitative Literacy	Pennsylvania	Community College
Boatman	2021	Statistics, College Algebra, Quantitative Reasoning	Tennessee	Community Colleges and Universities
Childers, Lu, Hairston, & Squires	2019	College Algebra, Quantitative Reasoning	Arkansas	University
Clinkenbeard	2021	Quantitative Literacy	California	University
Finder-Atkins & Stockdale	2017	Algebraic Modeling, Quantitative Literacy		Four-Year Institution
Kashyap & Matthew	2017	Quantitative Reasoning	Massachusetts	University
Logue, Douglas, & Watanabe-Rose	2019	Statistics	New York	Community College
Logue, Watanabe-Rose, & Douglas	2016	Statistics	New York	Community College
Matz & Tunstall	2019	College Algebra, Quantitative Literacy	Michigan	University
Perez & Hansun	2018	Quantitative Literacy	Massachusetts	University
Wakefield	2020	College Algebra, Quantitative Reasoning	Ohio	University

Overwhelmingly, across these fourteen studies, the authors found positive outcomes for student success for those enrolled in the corequisite mathematics model compared to the traditional developmental mathematics model.

Student Placement Criteria for Corequisite Mathematics Courses

In the last ten years, there have been significant efforts by math faculty and advocacy organizations, such as the Carnegie Foundation and the Charles A. Dana Center at The University of Texas at Austin, to redesign the math curriculum and course options to align higher education math course requirements to students' programs of study (Logue et al., 2019; Kashyap & Mathew, 2017). As reform has shifted students toward the right math course or sequence of courses for their program of study, math faculty have widely questioned the efficacy of standardized testing as the sole measure of student placement into mathematics courses and have called for the increased use of alternative placement methods and protocols (Perez, 2018; Ran & Lin, 2022; Kashyap & Mathew, 2017; Park et al., 2018). For the thirty-four articles in this literature review, student placement was a common theme of the corequisite mathematics models. However, such studies revealed that the placement criteria were as varied as the institutions implementing them. Further, detailed information about the placement criteria used to support student enrollment in a corequisite mathematics course and the introductory, college-level math course was largely missing.

Although the articles did not contain specific information about student placement criteria, a few general placement criteria seem to be what institutions prefer for student placement. Broad placement criteria loosely identified in the articles included high school grade point average (GPA), standardized assessment tests generated by for-profit companies (e.g., SAT, Aleks, Accuplacer), and locally generated in-house tests from the math department at an institution (Andrews, 2021; Atkins, 2016; Beamer, 2021b; Perez, 2018; Wakefield, 2020). Typically, a single cutoff score was used to identify appropriate math course placement, including if a student had to enroll in a corequisite mathematics course. For most reviewed articles, the placement cutoff score rarely considered the nuances of math content that a student had mastered versus math content that a student had not mastered. The result was that some students might have to complete an entire course when a math deficiency in only a small portion of a topic most influenced the placement score, an issue particularly evident in an exemption method model (Smith, 2019).

Understanding the limitations of using a single placement criterion for student placement, some institutions redesigned their placement protocols to use a multiple measures approach (Beamer, 2021b). Some student placement reforms designed to improve access and ultimately success in introductory college-level mathematics courses, such as one in Florida, removed traditional testing-based placement altogether, instead focusing on previous credentialing, e.g., an exemption based on a diploma from an in-state high school or military service (Mokher et al., 2021). Students involved in the reform were allowed to take developmental mathematics coursework to remediate known or perceived mathematics deficiencies; however, it was not mandated. Though sometimes incorporated into other placement mechanisms, self-selection or directed self-placement, as a student placement criterion, has gained traction in the spirit of student empowerment and participation in the educational process (Mokher et al., 2021; Clinkenbeard, 2021; Minsu Kim et al., 2018). A model used uniquely in the University System of Georgia (USG) is not included in the following table. In contrast to Florida's approach, the USG uses an exemption-method model. Rather than trying to determine the optimal placement for every student at the point of enrollment, USG enrolls every student in a corequisite math model as a default placement. Students are then allowed to test in a different course or satisfy the requirements in another manner, such as a high school GPA, an optional placement test score, or an optional entrance exam (Smith, 2019). Table 4 outlines the broad placement criteria found across many reviewed articles (21 of 34).

Table 4

Placement Criteria in Reviewed Articles

Author(s)	Article Publication Year	High School GPA	Standardized Assessment Tests	In-House Test	Exemption	Self-Selection Directed Self-Placement
Andrews & Tolman	2021	X	X			
Atkins & Beggs	2017		X			X
Atkins & McCoy	2016	X	X			
Beamer	2021b	X	X			
Boatman	2021		X			
Boatman, Claro, Fresard, & Kramer	2021			X		
Buckles, Haydel, Thompson-Sanchez, & Page	2019		X			
Childers, Lu, Hairston, & Squires	2021		X			
Clinkenbeard	2021	X	X			X
Goyer, Lynch, & Wand	2021		X			
Hancock, Franco, Bagley, & Karakok	2021		X			
Kane et al.	2021		X			
Kashyap & Mathew	2017	X	X			
Kim, Hebda, Graveman, & Hebda	2018				X	
Mokher, Park-Gaghan, & Shouping	2021					X
Perez & Hansun	2018		X			
Ran & Lin	2022		X			
Smith	2019				X	
Turner	2008			X		X
Vestal, Brandenburger, & Furth	2015		X			
Wakefield	2020		X			

Note. The multimodal column requires that two or more options be used for placement, not just offered as options. If an institution allowed more than one placement option but did not require all of them, each option was counted separately.

Design of Corequisite Mathematics Model

Corequisite mathematics courses have become increasingly used to support students identified as academically underprepared to access and complete introductory, college-level mathematics coursework. Corequisite mathematics courses may address the mathematics content traditionally taught in stand-alone dev-ed mathematics courses (Boatman, 2021; Wakefield, 2020; Finder-Atkins et al., 2017), or they may be designed to provide just-in-time academic support aligned to the introductory, college-level mathematics course, commonly called the target mathematics course when aligned to corequisite mathematics remediation. Target mathematics courses span multiple pathways, including quantitative reasoning courses (Clinkenbeard, 2021), statistics (Douglas et al., 2022), college algebra (Buckles et al., 2019), precalculus (Goyer et al., 2021), and calculus (Hancock et al., 2021). Aside from the general definition of a corequisite mathematics course noted in the Introduction section and widely agreed upon in the reviewed articles, the authors of this literature review found some common design characteristics across corequisite mathematics models, including faculty experience teaching corequisite mathematics courses, use of online, self-paced curricular materials, use of non-standard pedagogical practices, and incorporation of student success skills (e.g., self-regulation, soft skills).

Table 5 illustrates the corequisite mathematics model design characteristics found across the reviewed articles. These design characteristics are not disjoint. The first common design characteristic was met by indicating that the corequisite mathematics model/course was taught by faculty with experience teaching the target mathematics course. Additionally, graduate students, undergraduate students who performed well in their mathematics courses, or faculty without prior experience teaching the target mathematics course may have taught corequisite mathematics courses. Teaching students may not have received training before leading a corequisite. Some reviewed articles did not indicate the instructor type or describe an instructor who was not faculty with target course experience. The following two common design characteristics described corequisites that utilized a self-paced, online learning tool and included non-standard pedagogical practices. This literature review defines non-standard pedagogical practices as practices other than traditional lectures. Across the reviewed articles, eleven (32 percent) utilized non-standard pedagogical practices that emphasized instructional practices that were student-centered, active learning, and small group work. These common design characteristics were often identified as supporting a high level of student engagement in the corequisite mathematics courses. Only five (15 percent) of the reviewed articles demonstrated common design characteristics of incorporating student success skills in the curricular materials; these embedded skills included student self-regulation, study skills, and academic behaviors.

Table 5
Common Design Characteristics of Corequisite Mathematics Models

Author(s)	Year of Article Publication	Faculty teaching corequisites have target course experience	Corequisite design uses online, self-paced curricular materials	Non-standard pedagogical practices use in corequisite design	Embedded student success skills in curricular materials
Beamer	2021b	X		X	
Buckles, Haydel, Thompson-Sanchez, & Page	2019		X	X	
Childers, Lu, Hairston, & Squires	2019	X			
Clinkenbeard	2021	X	X		X
Finder-Atkins & Stockdale	2017	X		X	X
Goyer, Lynch, & Wand	2021	X		X	X
Hancock, Franco, Bagley, & Karakok	2021	X	X	X	X
Jaafar, Cornelius, Zaritsky, Evering, & Pal	2021			X	
Kashyap & Matthew	2017	X			
Logue, Douglas, & Watanabe-Rose	2019			X	
Logue, Watanabe-Rose, & Douglas	2016	X			X
Kim, Hedba, Graveman, & Hedba	2018	X		X	
Reinholz	2017			X	
Turner	2008			X	
Vestal, Brandenburger, & Furth	2015	X		X	
Wakefield	2020		X		

Other design characteristics for corequisite mathematics models, such as total number of contact hours, student assessment methods, faculty preparation, and curricular alignment between the corequisite course and target course, were minimal across the reviewed articles and not readily identified in Table 5. Another important finding across the reviewed articles was the measures used to determine corequisite mathematics course success. All thirty-four articles suggested that students were overwhelmingly successful in the corequisite and target mathematics courses. Thirty-one (91 percent) articles measured student success in the corequisite mathematics course via the course grade from the target mathematics course. At the same time, three studies identified student success based on course success in a subsequent mathematics course or degree completion. One study (Kane et al., 2021) claimed holistic student success in evaluating corequisite mathematics courses as a cost-effective form of remediation. Two other studies used qualitative measures to claim success. For example, Reinholz (2017) surveyed students to determine their sense of belonging, and Hancock et al. (2021) used interviews with faculty and students, written reflections, and classroom observations to further assess student success.

Table 6

Student Success Measures Across Reviewed Articles

Articles Reviewed	Grade in Target Math Course	Grade in Subsequent Math Courses and/or Degree Completion	Cost-Effective	Surveys
34	31	5	1	2

Discussion and Implications

To assist higher education practitioners, this literature review was intended to demonstrate the known research, evidence, and diversity of implemented corequisite mathematics models for prevailing commonalities across peer-reviewed articles. Commonalities found in the peer-reviewed articles about corequisite mathematics models suggest a wide variety of implementation efforts across the United States and continued confirmation that the corequisite mathematics model is a better solution for academic remediation than traditional prerequisite mathematics courses. However, the findings in this literature review produced critical implications and possible gaps in corequisite mathematics models for peer-reviewed research studies.

One common theme from the literature review suggested that implementing multiple mathematics pathways and corequisite remediation improved the effectiveness of the remediation reform effort and student success compared to the traditional algebra pathway (Ran & Lin, 2022; Andrews & Tolman, 2021). Although only directly tied in two studies and indirectly tied in fourteen studies, combining corequisite mathematics remediation reform and mathematics pathways reform is a worthy consideration to increase student success in introductory, college-level mathematics. Higher education practitioners seeking to adopt or amplify their existing corequisite remediation efforts should expand their activities to include mathematics pathways. Both professional literature and research studies that did not qualify for inclusion in this literature review support the assertion that mathematics pathways and corequisite remediation work better together, directly implying greater student success in students' introductory, college-level mathematics courses (Logue, 2018; Jenkins et al., 2018; Hartzler & Blair, 2019). Only 41 percent of the reviewed articles in this literature review examined corequisite mathematics course success in alternate mathematics pathways (e.g., statistics, quantitative reasoning), which suggests a misalignment with national norms that strongly advocate for mathematics pathways implementation (Center for American Progress, 2019).

The second theme from the literature review reported on student placement criteria, which suggested that the most popular placement criterion for corequisite mathematics models is still traditional standardized tests (e.g., SAT, ACT, Accuplacer, etc.). However, more options for in-house tests are rising in popularity. Albeit, both placement criteria emphasize a single data point for college-level mathematics readiness. The literature review indicates that an increasing number of institutions offer multiple attempt options and multimodal options for allowing students to place into a given mathematics course. In the multiple attempts model, though remediation is always an option for the individual student, a progressive move being implemented by some institutions is the advent of structured, focused remediation between attempts. This is especially popular with the use of the ALEKS platform. In the multimodal models, additional data points such as high school grade point average (GPA), previous mathematics course completion, standardized tests, and program of study play a role in identifying the appropriate mathematics course in which a student will be enrolled. A potential deficiency in the literature regarding corequisite mathematics courses is normalizing reporting placement methodology, especially when it influences the research topic itself. Nine of thirty-four articles did not clearly identify how students were placed into the corequisite mathematics courses. Nevertheless, all thirty-four articles did not include explicit details of placement criteria but a reference to which placement criteria were used (e.g., standardized test versus placement policy details, as seen in Figure 1). The immense diversity in placement criteria used across the reviewed articles leaves higher education practitioners questioning which measure(s) predict greater student success in corequisite mathematics courses and their aligned introductory, college-level mathematics courses.

<table>
<tr><th></th><th>Unweighted High School GPA</th><th>Transfer In of College Credits</th><th>ACT</th><th>SAT</th><th>Next-Generation Accuplacer</th><th>Accuplacer</th></tr>
<tr><td>Reading</td><td rowspan="4">2.5 or higher</td><td rowspan="4">C or better in a subject area</td><td rowspan="4">19 or higher</td><td rowspan="4">510 or higher</td><td>250</td><td>75</td></tr>
<tr><td>Writing</td><td>250 or 5</td><td>80 or
70-79 plus WritePlacer of 5 or above</td></tr>
<tr><td rowspan="2">Math</td><td rowspan="2">250</td><td>Arithmetic = 70</td></tr>
<tr><td>Elem. Algebra = 74</td></tr>
</table>

Figure 1. Academic Proficiency Placement Criteria used at Oklahoma State University Institute of Technology for Reading, Writing, and Mathematics in 2022-23. The 2022-23 academic catalogue informed academic proficiency guidelines. The details of this placement criteria are critical for higher education practitioners to assess effectiveness regarding how students were placed into the corequisite mathematics model and how they succeeded.

Finally, the last theme commonly found across the reviewed articles—the design of corequisite mathematics models—does not adequately explain the effectiveness of corequisite course design characteristics. For example, ten of thirty-four articles found that instructors/faculty teaching corequisite mathematics courses had experience teaching the target mathematics course. This commonality in course design and implementation begs the question of impact: *Does this common design characteristic for corequisite mathematics courses impact student success?* The same question can be asked about other common corequisite course design characteristics. Higher education practitioners rely on peer guidance and support from known evidence and research to inform corequisite mathematics course development and implementation activities. Details such as instructor/faculty preparation, contact hours and timing, pedagogical practices, student assessment, integration of student success support, the quantity of prerequisite content coverage, and details of attention to non-mathematical content (e.g., growth mindset, student self-regulation) are largely missing from the current research on corequisite mathematics courses. Further, most of the articles in this review defined student success based on course grades, with minimal consideration given to qualitative measures to assess corequisite mathematics course success. This gap in the literature leaves many unanswered questions about course design for institutions looking to implement their corequisite mathematics model.

Possibly, one of the most significant implications of this literature review is the recognition that numerous models planned to assist students in successfully completing their introductory college-level mathematics course have demonstrated some success. Thus, all successful models should be valued and none eschewed. Additionally, this study reveals that no one size fits all. Different university situations can effectively use different models. This topic warrants further investigation.

Future Research Recommendations

The findings of this literature review open ample opportunity for future research on corequisite mathematics models that can serve practitioners in their own implementation and continuous improvement activities. First, more research should be conducted on student success in corequisite mathematics courses and mathematics pathways. This research should expand to include additional mathematics pathways, such as data sciences, mathematics for elementary education, and mathematical modeling. Also, future research should disentangle the corequisite mathematics model and mathematics pathways findings to identify the nuances of each education reform's impact on student success in introductory, college-level mathematics. Further, future research should examine higher education student trajectories and progress through mathematics pathways, including those that change their major with different mathematics requirements; these data should focus on long-term student degree completion. Second, future research opportunities are needed to deepen our understanding of which design characteristics of corequisite mathematics models most impact student success and student experiences in mathematics. For example, researchers could consider the impact of a corequisite mathematics course on students' perceptions of mathematics and of themselves as productive learners of mathematics and their future careers. For higher education instructors/faculty, future research should focus on innovative pedagogical practices and their implications for student motivation, engagement, and success.

Conclusion

Many higher education institutions have adopted corequisite mathematics models to assist students in successfully completing their introductory college-level mathematics course in their first year of college. While the impact of these corequisite mathematics models is promising, the diversity of the implemented models, as described in the peer-reviewed literature, yields no clear format that other institutions can easily replicate. Instead, commonalities found in the peer-reviewed articles about corequisite mathematics models suggest a wide variety in implementation efforts across the United States and continued confirmation that the corequisite mathematics model is a better solution for academic remediation than traditional prerequisite mathematics courses.

References

*All references with an asterisk were included in the thirty-four articles for the literature review findings.

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