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The landscape of US elementary mathematics teacher education: course requirements for mathematics content and methods

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Abstract
The adequate preparation of future teachers of mathematics is critical, requiring sufficient opportunities to develop both pedagogical skill and content knowledge. Yet, despite new recommendations for mathematics teacher preparation, we know little about the landscape of course-based learning opportunities in US elementary teacher education programs. To what extent do US elementary teacher education programs meet the *Standards for Preparing Teachers of Mathematics* outlined by the Association of Mathematics Teacher Educators (AMTE) for mathematics content and methods courses? Based on an a priori power analysis, we gathered a random sample of 291 higher education institutions. Within these institutions, we analyzed 736 programs, including Bachelor's, Master's, and Credential programs. We found that overwhelmingly US elementary teacher education programs do not meet the aspirations outlined in the AMTE standards, with Master's and Credential programs and those covering all elementary grades particularly falling short. Potential explanations for these challenges and implications for teacher education program design are discussed.

Keywords Mathematics teacher education · Teacher preparation · Elementary mathematics · Mathematics methods

Teacher educators in the US have long noted the challenges of preparing pre-service teachers (PSTs) to enter the profession, particularly in the limited time allotted by their programs (Saclarides et al., 2022; Berry, 2004). There are many important areas for PST learning, including content knowledge, pedagogical content knowledge, knowledge of

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student thinking and learning trajectories, instructional strategies, student engagement, and appropriately planning instruction for students with diverse learning needs (Shulman, 1986; Simon, 1995). Moreover, PSTs must develop understanding of how funds of knowledge and cultural experiences are essential to students' learning (Moll, 2019). For many teacher education programs in the US, it is difficult to find time to adequately address all of these topics (Cochran-Smith et al., 2015). This issue is exacerbated for elementary teacher education programs, which typically prepare PSTs to teach multiple content areas across a wide range of grade levels.

High-quality teacher preparation is especially important in elementary mathematics. Studies of elementary PSTs' experiences with mathematics indicate that they often enter teacher education programs with math anxiety (Beilock et al., 2010; Bursal & Paznokas, 2006), which can, in turn, negatively influence their effectiveness when they enter the classroom (Stoehr & Olson, 2015). Teachers' anxiety about teaching mathematics can impact their instructional choices, expectations of students, and student achievement (Hadley & Dorward, 2011; Mizala et al., 2015). As with all content areas, PSTs must deeply understand mathematics content, as well as how to teach mathematics. Yet, many elementary PSTs do not enter teacher education programs with adequate knowledge of mathematics (Ball et al., 2008; Scheibling-Sève et al., 2020), and therefore, elementary teacher educators must provide opportunities to support PSTs' knowledge of both mathematics content and mathematics pedagogy.

To inform mathematics teacher education programs, the Association of Mathematics Teacher Educators (AMTE)—the major professional organization of mathematics teacher educators in the US, which aims to improve K-12 mathematics teacher education—has outlined a set of *Standards for Preparing Teachers of Mathematics* (SPTM; AMTE, 2017). Building on and synthesizing previous efforts to describe goals for PSTs' mathematical content knowledge (e.g., Conference Board of Mathematical Sciences, 2012) and pedagogical knowledge (e.g., Council for the Accreditation of Education Preparation, 2013), the SPTM addresses mathematics teacher preparation across PreK-12. Specifically, the SPTM outlines the knowledge, skills, and dispositions that well-prepared beginning mathematics teachers should learn in teacher education programs. The SPTM also includes recommendations for courses and clinical experiences that stand to support PSTs' development of the recommended knowledge, skills, and dispositions. Importantly, the SPTM is intended to be aspirational, aiming for the development of "high-quality teachers who are ethical advocates for children and effectively guide student learning aligned with research and best practices" (p. xiv), rather than aiming for bare minimum requirements that teacher preparation programs must adhere to.

Yet, the field of mathematics teacher education knows little about how well US teacher education programs align with the expectations outlined by AMTE. While some studies have surveyed mathematics faculty about mathematics requirements for elementary PSTs (e.g., Masingila & Olanoff, 2021; Masingila et al., 2012), they rely on self-reported survey data, which may result in a sample that is not representative of the overall population. They also do not take into account the grade bands that PSTs are being prepared to teach. As mathematics teacher educators, we realize that the recommendations in the SPTM are challenging to enact—indeed, our own programs require fewer mathematics education courses than AMTE recommends. As a result, we also recognize that it is difficult to adequately prepare elementary PSTs to teach mathematics with few courses in mathematics content and methods. However, the current landscape of elementary mathematics teacher preparation in the US in relation to the SPTM is hazy, and we seek to add clarity to this issue.

In this analysis, we address the following question: To what extent do US elementary teacher education programs meet AMTE's recommendations for the number of credits in mathematics content and methods, as outlined in the SPTM? In other words, how widespread is the issue of limited mathematics content and methods courses in elementary teacher education programs? We examine the landscape of US elementary mathematics teacher education, analyzing course credit requirements—both for learning mathematics and learning to teach mathematics—in light of the course recommendations in the SPTM. We find that insufficient opportunities for PSTs to learn mathematics and to learn to teach mathematics are not an isolated problem for individual programs; rather, they are a widespread systemic issue, affecting most elementary teacher education programs in the US.

While we focus our analysis on the US, we view this as a case of a larger phenomenon that is present in other countries. Many countries—including Singapore, Finland, Canada, and Australia—have introduced significant reforms in the realm of teacher preparation (Stewart, 2012). In the US, AMTE has been central to these efforts; the SPTM reflects AMTE's efforts to influence the design of teacher preparation programs. Yet, AMTE has no direct authority over licensure requirements or teacher education programs. Our analysis raises questions about the effectiveness of external standards in shaping teacher preparation requirements. Moreover, international measures for educational performance are frequently used to motivate educational reforms across the globe (Stewart, 2012; Mullis et al., 2016). One contribution of this piece is to understand how the US system works for preparing elementary teachers, thereby contributing to the broader conversations about international comparisons.

Background

To create a unified vision for the preparation of US mathematics teachers across PreK-12, AMTE synthesized existing research in teacher education and built on prior standards for teacher preparation. Prior documents captured parts of the field: For instance, the Mathematical Education of Teachers II (MET II; CBMS, 2012) summarized the mathematical content knowledge that PSTs should learn to teach at the elementary, middle, and high school levels. Similarly, the Council for the Accreditation of Educator Preparation Standards (CAEP, 2013) addressed the pedagogical knowledge that PSTs should learn across content areas and grade levels.

We specifically chose the SPTM as a guide for this research because of its dual focus on PSTs' opportunities to learn mathematics content and mathematics pedagogy. Indeed, the SPTM includes many of the mathematical content recommendations from MET II (CBMS, 2012). For instance, both MET II and the SPTM underscore the importance of PSTs' deep conceptual understanding of key ideas in elementary mathematics. Additionally, the SPTM elaborates on the need for PSTs to learn about mathematics pedagogy, a point that MET II does "not [discuss] in detail" (CBMS, 2012, p. 23). At the same time, the CAEP standards (CAEP, 2013) highlight the importance of PSTs' development of pedagogical knowledge and skills, but they do so from a content-neutral perspective. In these ways, the SPTM builds on prior recommendations for teacher preparation, but with complementary emphases on both mathematics content and pedagogical methods. Moreover, by making distinct recommendations for coursework in mathematics content and methods—and for both early childhood and upper elementary grade bands—the recommendations outlined in the SPTM

allow us to develop more detailed findings about *how* programs fall short of guidance from AMTE, a leading professional organization.

Mathematical knowledge for teaching

Scholars in teacher education have paid much attention to the knowledge and skills that PSTs and in-service teachers need in order to be effective educators (Ball & Bass, 2003; Ball et al., 2005; Carpenter et al., 1988; Hill et al., 2008; Shulman, 1986). For mathematics teachers, this is referred to as Mathematical Knowledge for Teaching (MKT; Ball, 1990; Hill & Ball, 2009). Ball and colleagues (2008) outlined various components of MKT, broadly grouped into subject matter knowledge and pedagogical content knowledge. Subject matter knowledge refers to knowledge of mathematics, including topics that most people would use in their daily lives (e.g., arithmetic operations) and topics that are more specific to teaching (e.g., terms like "subtrahend" that refer to specific parts of operations), as well as horizon content knowledge (e.g., how arithmetic concepts develop over time). Pedagogical content knowledge refers to knowledge of the intersections among mathematics, students, and teaching—essentially, how to plan and implement lessons in ways that will support students' conceptual understanding. Hill and colleagues (2005) have found a strong and significant positive association between teachers' MKT and the quality of their math instruction. Furthermore, they found that teachers' MKT positively predicted gains in student achievement.

The importance of MKT points to a key tension in elementary teacher education: preparing teachers to be content generalists or content specialists. Based on the research that MKT is central to improving classroom instruction, some researchers have proposed that elementary school teachers become content specialists (e.g., Li, 2008), as teachers typically are in secondary schools. This is supported by studies contrasting the mathematical knowledge of elementary school teachers in the US and China. For example, Ma (1999) found that elementary teachers in China performed higher on a mathematics assessment than their counterparts in the US. One reason for this discrepancy, according to Li (2008), might lie in the fact that US elementary teachers are typically content generalists, while Chinese elementary teachers specialize in teaching mathematics. This focus on a single topic likely contributes to improved performance relative to their US counterparts, who have to divide their content studies over a greater variety of topics.

Given that elementary teachers in the US—and many other countries—are typically responsible for teaching multiple subjects, this places high expectations on the knowledge and skills that they must develop to teach all content areas across all elementary grades. We recognize that there are many important skills, dispositions, knowledge domains, and pedagogical practices PSTs need to develop in order to become effective educators. In this analysis, we focus on PSTs' opportunities to learn mathematics and to learn to teach mathematics. In the section that follows, we describe our conceptual framework that guided this analysis.

SPTM recommendations for elementary PSTs' opportunities to learn

To examine elementary mathematics teacher preparation, we draw on the SPTM (AMTE, 2017). AMTE is the largest professional organization devoted to the improvement of mathematics teacher education in the US; the SPTM reflects AMTE's efforts to guide teacher preparation programs. Drawing on decades of research in mathematics teacher education,

the SPTM outlines recommendations for PSTs' *opportunities to learn mathematics* and *opportunities to learn to teach mathematics*; we organize our analysis around these constructs. In university-based teacher preparation programs, these opportunities primarily come through mathematics content courses and mathematics methods courses, respectively. According to the SPTM, an effective mathematics teacher preparation program provides PSTs with opportunities to learn mathematics by purposefully focusing on "essential big ideas across content and processes that foster a coherent understanding of mathematics for teaching" (p. 26). At the same time, an effective program provides opportunities to learn to teach mathematics by providing PSTs with learning experiences through "mathematics-specific methods courses in which mathematics, practices for teaching mathematics, knowledge of students as learners, and the social contexts of mathematics teaching and learning are integrated" (p. 26).

The SPTM is further delineated by grade band, including early childhood (PreK through Grade 2) and upper elementary (Grades 3 through 5). While the content knowledge for each of these grade bands is related, they are distinct. To be well prepared to teach early childhood mathematics, PSTs need to learn content such as counting and cardinality, the base-ten place-value system, the foundations of algebra—including addition, subtraction, multiplication, and division—and the foundations of geometry, measurement, and spatial sense. For upper elementary mathematics, PSTs need to be well versed in topics such as multiplication and division, fractions and decimals, data analysis, and more advanced knowledge of geometry and measurement. While many teacher education programs prepare PSTs to teach in both early childhood and upper elementary grades, AMTE's recommendations emphasize the importance of devoting adequate instructional time to content in each grade band: 3 credit hours of early childhood mathematics content courses and 12 credit hours of upper elementary mathematics content courses.

The recommendations for mathematics content outlined in the SPTM are comparable to—but somewhat stronger than—recommendations in other reports, including MET II (CBMS, 2012). MET II recommends that elementary teacher preparation programs include 12 credit hours for PSTs seeking licensure to teach Grades K-5. This is three credits fewer than AMTE's recommendations of 3 credit hours of content in Early Childhood mathematics and 12 credit hours of content in Upper Elementary mathematics. Indeed, the SPTM describes the MET II recommendations as the "minima for effective mathematics teacher preparation" (AMTE, 2017, p. 29). Furthermore, MET II acknowledges that PSTs with limited mathematics experience will need additional preparation in mathematics (CBMS, 2012); this includes many elementary PSTs (Gresham, 2007; Lee & Zeppelin, 2014; Vinson, 2001). For these reasons, we interpret the SPTM as indicating that 15 credit hours of mathematics content—that is, 3 credit hours in Early Childhood and 12 credit hours in Upper Elementary—are recommended to adequately prepare elementary PSTs to teach all levels of elementary mathematics. We view the SPTM as providing recommendations that include and extend the work of MET II, while also highlighting the need for PSTs to learn mathematics deeply across many grade levels. Requiring 15 credit hours of mathematics content may be ambitious for many teacher education programs, but the SPTM represents aspirations for the field, rather than bare minimum requirements.

The SPTM also outlines expectations for elementary PSTs to learn to teach in mathematics methods courses. Building on PSTs' knowledge of mathematics content, effective teacher education programs include opportunities for PSTs to learn to support students' conceptual understanding, procedural knowledge, and mathematical fluency (AMTE, 2017; CBMS, 2012). PSTs also need opportunities to learn about planning and implementing mathematics instruction that is accessible and equitable for all of their students, particularly

students with disabilities, multilingual students, students of color, LGBTQ + students, and students at the various intersections of those identities (SPTM, 2017). Furthermore, PSTs must learn about various formative assessment strategies to gauge students' mathematical understanding, and how to analyze student data to inform future instruction. Finally, PSTs must learn how to facilitate productive discursive communities in their classrooms that value student sensemaking, reasoning, and productive struggle. Just as PSTs must learn to teach mathematics content for each grade band, they must learn pedagogical approaches that are developmentally appropriate to the grades they will teach. Accordingly, AMTE recommends 3 credit hours of Early Childhood mathematics methods and 3 credit hours of Upper Elementary mathematics methods. As with the recommendations for coursework in mathematics content, we interpret the SPTM as indicating that 6 credit hours of mathematics pedagogy are recommended to adequately prepare elementary PSTs to teach all levels of elementary mathematics.

Importantly, we recognize that these two dimensions—opportunities to learn about mathematics and opportunities to learn to teach mathematics—are not entirely separable. Indeed, they are interconnected and build on one another. For example, PSTs must understand fractions in order to understand pedagogical approaches to teaching fractions, and learning to teach fractions in conceptually rich ways may, in turn, deepen PSTs' own understanding of fractions. Whether in overlapping or distinct experiences, teacher education programs should offer sufficient course-based opportunities for PSTs to learn both mathematics and how to teach mathematics (AMTE, 2017; CBMS, 2012).

Following the framing of the SPTM and MET II, we view program course requirements as necessary, but insufficient, for ensuring that elementary PSTs learn mathematics and how to teach mathematics. Even with many required courses in mathematics and pedagogy, PSTs are unlikely to learn if the courses are not designed or implemented in ways consistent with the intent of the SPTM. However, without time dedicated to the serious study of mathematics and teaching mathematics—that is, without courses in mathematics content and methods—teacher preparation programs are unlikely to have sufficient time and space to provide adequate opportunities to learn.

At the same time, we also recognize that teacher preparation programs can provide opportunities to learn about mathematics—and how to teach mathematics—outside of required courses. For example, PSTs might take additional elective courses, participate in book clubs, attend mathematics education conferences, or learn from experienced mathematics teachers online. PSTs also have significant opportunities to learn through student teaching and other clinical experiences; indeed, the SPTM outlines additional expectations for these areas of teacher preparation. For the purposes of this analysis, however, we focus on PSTs' opportunities to learn in courses required by elementary teacher education programs in US colleges and universities.

Methods

To answer our research question, we used random sampling to select institutions of higher education for analysis. Using each institution's website, we collected data on course requirements for teacher education programs at each institution within our sample. Our analysis focused on the program requirements, which we compared to AMTE's recommendations, as outlined in the SPTM.

Table 1 Regional strata for sample size

Region	Number of institutions in sampling frame (N)	Number of institutions in sample (n)
Northeast	256	62
Midwest	318	77
South	444	107
West	188	45
Total	1206	291

Sample

We performed an a priori power analysis to estimate the sample size. Based on data from the National Center for Education Statistics (NCES, 2018), we determined a sample frame of $N = 1206$ elementary teacher education programs. Our sample frame included all US colleges and universities that offer credentials—bachelor's degrees, master's degrees, or post-baccalaureate certificates—that lead to initial teacher licensure. With an alpha of 0.05 and power of 0.80, the projected sample size needed with this effect size is $n = 291$. We stratified the sample according to the number of institutions in four geographical regions—Northeast, South, West, and Midwest (U.S. Census Bureau, 2018)—thereby ensuring representation of institutions across the US.

Using the information reported by the NCES (2018), we determined the number of institutions in each state and the total number of institutions in each of the four regions. To calculate the stratification of the sample, we compared the number of institutions in each region to the population size ($N = 1206$) in order to obtain regional weights. We ensured that each region maintained the same relative weight in the sample taken. The number of institutions sampled by region is described in Table 1.

To select a stratified random sample, we used a random number generator to assign numbers to each institution in our sampling frame. We then ordered the institutions in each region by these random numbers and selected our sample based on the strata outlined in Table 1. By using random numbers to select the sample, we ensured that each institution had an equal chance of selection (Agresti & Finlay, 2009).

Data collection

We constructed a database of all sampled institutions by region. Data were drawn from publicly available sources on institutional websites, including teacher education program descriptions, student handbooks, and academic calendars. We did not collect data from course syllabi, as syllabi are not always publicly available or up-to-date; moreover, we were concerned with the number of required mathematics content and methods courses, rather than the content of those courses. If insufficient data were available on an institution's website—or if there was uncertainty or confusion about the information provided on the webpage—we reached out to the program by email or phone. If we could not obtain the information or clarification, or if the institution had recently closed

Table 2 Data collection and categorization

Variable	Description
Institution characteristics	
Academic terms	Semesters or quarters
Institution type	Public or private
Program types	
Credential awarded	Bachelor's degree, Master's degree, or Certificate
Grade band	Early Childhood, Upper Elementary, or All Elementary
Program requirements	
Math content courses	Number of semester credit hours
Math methods courses	Number of semester credit hours
Combination courses	Number of semester credit hours

their teacher education program, the institution was substituted with another in the same region. In such cases, we followed the same randomization process described above.

For each institution, we recorded the academic term type (i.e., semesters or quarters) and institution type[1] (i.e., public or private). We then gathered data on each teacher education program, which we describe below (see Table 2). Many institutions offer multiple programs for preparing elementary teachers—including programs for specific grade bands (e.g., early childhood or upper elementary), for different degrees (e.g., undergraduate or graduate), etc. Because different programs at the same institution typically have different course requirements, we collected data at the program level, rather than the institution level. This resulted in data from 736 programs from our sample of 291 institutions.

Program types

Each institution in our sample has at least one teacher education program for elementary teachers of mathematics. For each program, we collected the following data:

Credential. Each program awards graduates a *Bachelor's degree*, *Master's degree*, or *Certificate*. Teacher certificate programs lead to licensure, but do not grant a degree.

Grade band. Each program focuses on a specific grade band for teacher preparation, typically influenced by state licensure requirements. Initially, we documented the specific grade band for each program (e.g., PreK-3, K-5, K-8). To align this with AMTE's Standards for Preparing Teachers of Mathematics, we coded each program as one of three grade-band categories: (1) *Early Childhood*, or programs for teachers seeking certification in early elementary grades (defined by the SPTM as grades PreK-2), including K–2, K–3, and PreK–2; (2) *Upper Elementary,* or programs for teachers seeking certification in later elementary grades (defined in the SPTM as grade 3–5), including 3–6, 3–5, and 2–5; or (3) *All Elementary,* or programs for teachers seeking certification in all or most elementary grades, including K–6, K–5, PreK–6, and 1–6.

[1] We made sure to note if an institution was public or private as part of the data collection process, but we did not differentiate between public and private institutions in our analysis; our goal was to study the programs at each institution, not the institution type. The appendix describes the number of public and private institutions we sampled in each region.

Some programs, however, did not neatly match the grade bands listed in the SPTM. To determine codes for such programs, we focused on both *how many* and *which* grade levels PSTs were being prepared to teach. The grade bands in the SPTM cover three (grades 3–5) or four (grades PreK-2) grade levels. For programs that crossed these bands, we determined that any program preparing teachers for five or more grades (e.g., grades K-4) would be considered *All Elementary*, while any such program that prepared teachers for four or fewer grades (e.g., grades 2–5) would be coded by the grade band that contained the predominant number of those grades. For example, a program preparing PSTs to teach grades 2–5 addresses more upper elementary grades than early childhood grades, so it would be coded as *Upper Elementary*.

For this analysis, we excluded programs that certify PSTs for middle grades instruction, (e.g., K-8, 4–8). These programs were often disciplinary specialist programs certifying mathematics teachers with additional courses in the discipline. This study focuses on programs designed for elementary generalists, where mathematics is one of multiple subjects for which PSTs are being prepared to teach.

This process generated a total of 484 programs across the 291 institutions for additional data collection and analysis.

Program requirements

We recorded the mathematics courses required for each program, including course titles and credit hours. We narrowed our focus to required courses—i.e., courses that all elementary PSTs would need to take in order to graduate, regardless of the department in which they are listed. For each program, we collected the following data:

Course types. Using course titles and descriptions, we coded mathematics education courses as one of three categories: *Content, Methods,* or *Combination. Content* courses focus primarily on mathematics content knowledge for teaching elementary mathematics (e.g., ED 2860: Mathematics for Elementary Teaching, at the University of Minnesota—Crookston). *Methods* courses focus on the pedagogy of elementary mathematics (e.g., EDCI 4550: Methods in Teaching Elementary Mathematics, at Tennessee State University). *Combination* courses include both mathematics content and pedagogical methods (e.g., EED 342: Elementary Math Concepts and Methods, at Crown College). When course types were unclear from their titles and descriptions, we reviewed the courses together to come to a consensus.

Credit hours. Using institutions' course catalogs, we recorded the number of credit hours for each mathematics education course. For each program, we calculated the total number of credit hours required in each category—*Content*, *Methods*, and *Combination*.

While most programs in our sample use a semester-based academic calendar, a small number (10 programs, representing approximately 1% of our sample) use quarters. According to the U.S. Department of Education, "quarter credit hours represent proportionately less work than semester hours due to the shorter terms, about two-thirds of a semester credit hour" (U.S. Department of Education, 2008). Following this definition, we converted quarter credits to semester credits. Because one academic year is equivalent to two semesters or three quarters, we multiplied quarter credits by two-thirds to get the equivalent number of semester credits. One potential limitation of this method is that this may not capture the idiosyncrasies of each institution in our sample (e.g., schools that vary in the number of contact hours for each credit hour).

Table 3 AMTE's recommendations by program type

Grade band	Math methods	Math content	Total
Early Childhood	3 semester credits	3 semester credits	6 semester credits
Upper Elementary	3 semester credits	12 semester credits	15 semester credits
All Elementary	6 semester credits	15 semester credits	21 semester credits

Data collection process

Five of the authors created the structure and determined the components of the database. Two of the authors used Excel to construct the database itself. During this process, they split the database by regions to enter the data. Then, they met and cross-checked their data entries. They used formulas within Excel to highlight potential data errors for checking. Every two weeks, the two authors responsible for coding met with the remaining authors to discuss their findings, clarify questions, and make coding decisions based on the criteria described above.

Analytic methods

Recall that the SPTM outlines AMTE's recommendations for courses in both mathematics content (i.e., opportunities to learn mathematics) and mathematics methods (i.e., opportunities to learn to teach mathematics). These recommendations are also separated by grade band, with distinct standards for teacher preparation in early childhood and in upper elementary. The recommendations are summarized in Table 3.

To determine which programs meet AMTE's recommendations, we compared the credit hour requirements for each program to the recommendations in the SPTM (see Table 3). For programs leading to certification in early childhood or upper elementary, this comparison was straightforward. But, as we noted, many teacher education programs prepare teachers for all elementary grades. While the SPTM does not make explicit recommendations for PreK–6 programs, the standards do clearly state that the mathematics content and pedagogy for teaching early childhood and upper elementary is related, yet distinct. Accordingly, we argue that elementary PSTs seeking certification in all elementary grades need opportunities to learn mathematics content and methods in early childhood *and* upper elementary. To fully address the breadth and depth of PreK–6 mathematics content and pedagogy, we interpret the SPTM as indicating that *All Elementary* programs should require more courses than programs in just one grade band. Accordingly, for programs coded as *All Elementary*, we added the content and methods recommendations for Early Childhood and Upper Elementary. Again, the SPTM recommendations are aspirational, rather than the minimum requirements indicated in MET II (AMTE, 2017; CBMS, 2012).

We then coded each program with one of the following codes: *Meets neither content nor methods; Meets methods only; Meets content only; Meets both content and methods.*

Programs coded as *Meets neither content nor methods* meet neither the content nor methods recommendations outlined in the SPTM. This includes: (a) Early Childhood programs with fewer than 3 credits of math methods and fewer than 3 credits of math content, (b) Upper Elementary programs with fewer than 3 credits of methods and fewer than 12

credits of content, and (c) All Elementary programs with fewer than 6 credits of methods and fewer than 15 credits of content.

Programs coded as *Meets methods only* meet the methods recommendations outlined in the SPTM, but do not meet the content recommendations. This includes: (a) Early Childhood programs with at least 3 credits of math methods, but fewer than 3 credits of math content, (b) Upper Elementary programs with at least 3 credits of methods, but fewer than 12 credits of content, and (c) All Elementary programs with at least 6 credits of methods, but fewer than 15 credits of content.

Programs coded as *Meets content only* meet the content recommendations outlined in the SPTM, but do not meet the methods recommendations. This includes: (a) Early Childhood programs with at least 3 credits of math content, but fewer than 3 credits of math methods, (b) Upper Elementary programs with at least 12 credits of content, but fewer than 3 credits of methods, and (c) All Elementary programs with at least 15 credits of content, but fewer than 6 credits of methods.

Programs coded as *Meets both content and methods* meet both the content and methods recommendations outlined in the SPTM. This includes: (a) Early Childhood programs with at least 3 credits of math methods and at least 3 credits of math content, (b) Upper Elementary programs with at least 3 credits of methods and at least 12 credits of content, and (c) All Elementary programs with at least 6 credits of methods and at least 15 credits of content.

Findings

Our review of university-based elementary mathematics teacher education programs found that most do not meet AMTE's (2017) Standards for Preparing Teachers of Mathematics. In the following sections, we describe the distribution of programs that meet and do not meet these recommendations for elementary mathematics methods and content courses and analyze the features of these programs. Finally, for programs that fall short of these recommendations, we describe where and how they do so.

Distribution of teacher education program requirements

Recall that we used two units of analysis—*institutions* that prepare elementary PSTs and the *programs* that they offer—which offer two ways of understanding the preparation of elementary teachers of mathematics. Across our final sample of 484 programs, we found that 64% of programs ($n=312$) met neither AMTE's recommendations for mathematics methods course requirements nor the recommendations for mathematics content course requirements (Fig. 1). Moreover, 12% of programs ($n=59$) met only the recommendations for methods courses and 8% of programs ($n=38$) met only the recommendations for content courses, but not both. Just 15% of programs ($n=75$) fully met the recommendations for methods and content courses.

At the institution level, we also considered which institutions have at least one program in each category: does not meet recommendations, meets methods recommendations only, meets content recommendations only, and meets both recommendations. We determined the sampling distribution ($\hat{p}$) of the sample population and confidence intervals at a 95% confidence level (see Table 4). We found that 70.1% of institutions (SE = 0.053) have at least one program that does not meet either of AMTE's recommendations for

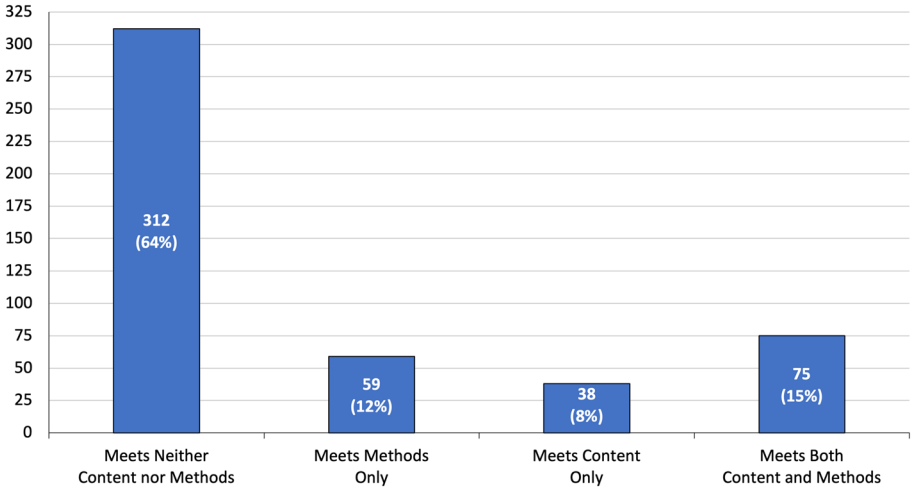

Fig. 1 Distribution of elementary teacher education programs meeting and not meeting AMTE recommendations

Table 4 Measures of dispersion at the institution level

Category	Estimate	SE	95% CI	
			LL	UL
Meets neither content nor methods	0.701	0.027	0.648	0.754
Meets methods only	0.168	0.022	0.125	0.211
Meets content only	0.124	0.019	0.086	0.162
Meets both content and methods	0.223	0.024	0.176	0.271

Estimates refer to the proportion of institutions with at least one program in each category. SE is standard error. CI is confidence interval. LL is lower limit. UL is upper limit

the preparation of elementary teachers of mathematics. Institutions that have at least one program that meets only the methods or content recommendations make up 16.8% (SE = 0.043) and 12.4% (SE = 0.038) of teacher preparation institutions, respectively. Only 22.3% (SE = 0.024) of institutions have at least one program that meets AMTE's recommendations for both methods and content course requirements. This last finding warrants pause, as it indicates that approximately three-quarters (77.7%) of institutions preparing elementary teachers do not have *any* program that meets AMTE's recommendations for mathematics content and methods.

Characteristics of elementary teacher education programs that meet and do not meet AMTE recommendations

To further analyze our data, we looked at the characteristics of programs that do and do not meet ATME recommendations. We found two program features that are especially consequential: grade band and credential type. Recall that we coded each program as preparing teachers to teach Early Childhood (e.g., PreK–2) or All Elementary (e.g., PreK–6).

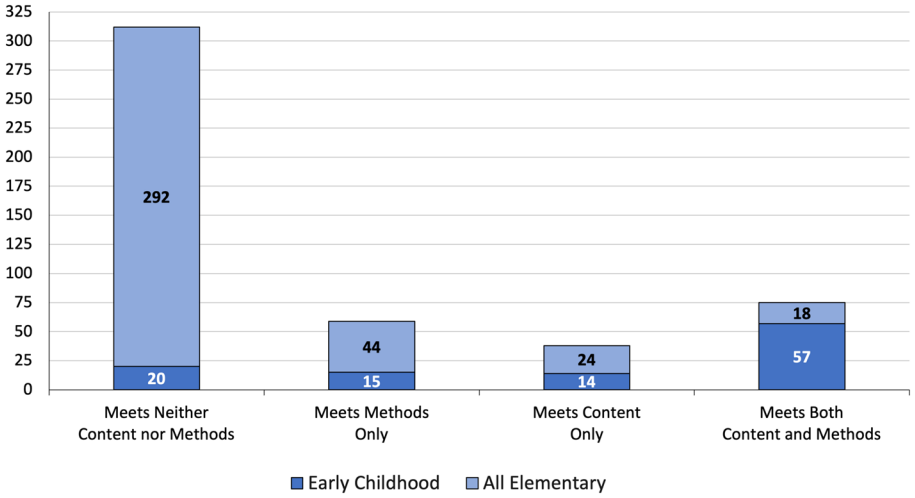

Fig. 2 Distribution of early childhood and all elementary grades programs meeting and not meeting AMTE recommendations

No programs in our final sample were focused solely on Upper Elementary (e.g., grades 3–5); all programs with grade bands beginning in upper elementary grades also extended through middle school grades and were thus excluded from our data set.

Comparing Early Childhood programs and All Elementary programs, we found that Early Childhood programs were more likely to meet AMTE recommendations (see Fig. 2). While Early Childhood programs made up only 21.9% ($n=106$ of 484) of the programs sampled, they comprised 76% ($n=57$ of 75) of the programs that met AMTE's recommendations for both content and methods courses. Indeed, most (81.1%; $n=86$ of 106) Early Childhood teacher education programs in our data met either or both of these recommendations, while the majority (77.2%; $n=292$ of 378) of programs for All Elementary grades met neither.

These findings are likely a feature of the recommendations themselves: The number of courses recommended by AMTE depends on the grade bands teachers are being prepared for, with fewer courses recommended for teachers being prepared for fewer grades of instruction. Early Childhood programs address one grade band in AMTE's recommendations (i.e., PreK–2), while All Elementary programs encompass two (i.e., PreK–2 *and* 3–5). Each grade band has its own recommendations, with fewer content and methods courses recommended for Early Childhood than Upper Elementary. Moreover, under our coding framework, All Elementary programs would need to meet both sets of requirements to meet AMTE's recommendations, which only 4.8% of All Elementary programs in our sample did.

The type of credential offered by each program was also influential in meeting (or not meeting) AMTE recommendations. Recall that we collected data on Bachelor's, Master's, and Certificate programs. As shown in Fig. 3, Bachelor's programs were most likely to meet all or some of AMTE's recommendations, constituting 98.7% of programs that met both content and methods recommendations, 97.4% of programs that met content recommendations only, and 62.7% of programs that met methods recommendations only. Overall, 46.1% ($n=147$ of 319) of Bachelor's-level elementary teacher education programs met

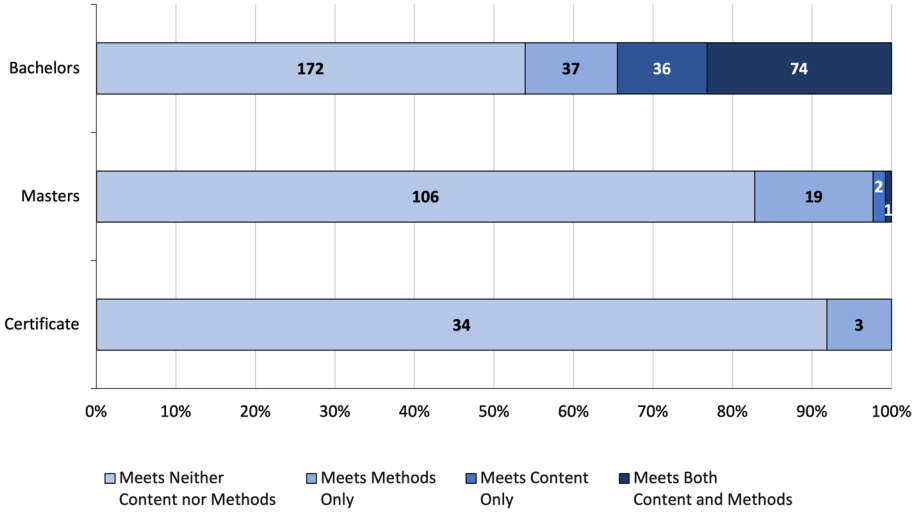

Fig. 3 Distribution of programs meeting and not meeting AMTE recommendations by degree type

either or both of AMTE's recommendations, compared to 17.2% ($n=22$ of 128) of Master's programs and 8.1% ($n=3$ of 37) of Certificate programs.

These findings are likely attributable to the structure of different degree programs: Bachelor's programs are typically four-year degrees, while Master's and Certificate programs are typically one or two years in duration. With fewer years of study, Master's and Certificate programs require fewer courses overall—including fewer math content and methods courses. Master's and Certificate programs typically require an undergraduate degree as a prerequisite; it is reasonable to assume that undergraduate degrees require some mathematics content courses. However, mathematics content courses for elementary teachers are unlikely to be a part of non-education undergraduate degrees; general college-level mathematics courses, such as college algebra or calculus, are not an adequate replacement (Masingila et al., 2012). This may, in turn, limit pre-service teachers' opportunities to develop Mathematical Knowledge for Teaching (MKT), which requires deeply understanding elementary math content in a way that fosters productive math instruction (Ball, 1990; Hill & Ball, 2008).

At the institution level, we compared public and private institutions and compared institutions in different regions. We found no significant difference between programs at public and private institutions with respect to the AMTE recommendations. However, some regional differences did emerge. As described in the methods section, our sample was stratified by the four U.S. Census Bureau regions: Northeast, Midwest, South, and West. As shown in Fig. 4, institutions in the Midwest were more likely to have at least one program that met content, methods, or both recommendations (45.8%; $n=60$ of 131) than the West (38.1%; $n=16$ of 42), Northeast (34.7%; $n=41$ of 118), or South (28.5%; $n=55$ of 193). Institutions in both the Midwest (23.7%) and West (23.8%) were more likely to have at least one program that met both content and methods recommendations than institutions in the Northeast (11.0%) or South (10.9%). While these regional differences are noteworthy, the source of these differences is outside the scope of our analysis.

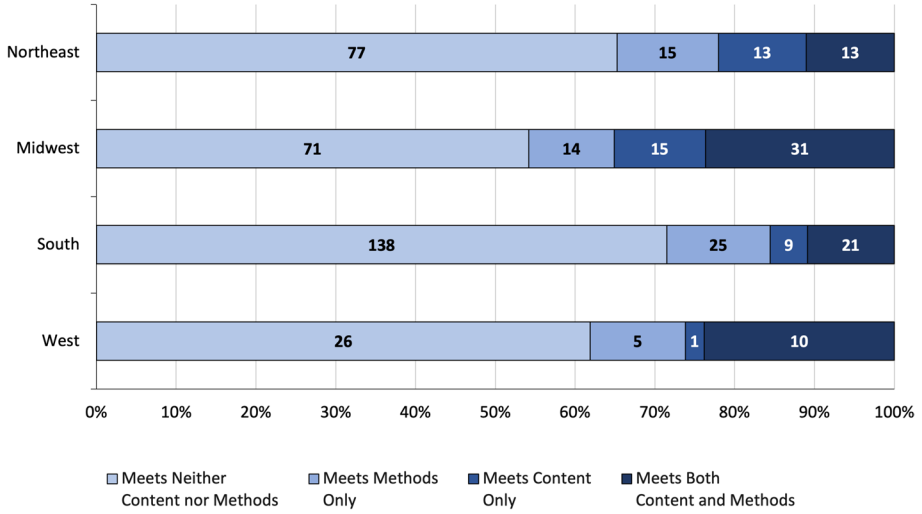

Fig. 4 Distribution of programs meeting and not meeting AMTE recommendations by region

Taken together, these patterns indicate that Early Childhood and Bachelor's programs—and institutions in the Midwest and West—were more likely to meet AMTE's Standards for the Preparation of Teachers of Mathematics. Master's and Certificate programs, programs for All Elementary grades, and institutions in the South and Northeast were less likely to meet AMTE recommendations.

How programs fall short of AMTE recommendations

The overwhelming majority of programs in our sample did not meet AMTE's recommendations for both content and methods courses (84.5%; $n = 409$ of 484). In our next analysis, we examine precisely how these programs fall short of the recommendations. We wondered: To what degree are programs narrowly missing the mark? Are they, perhaps, meeting the recommendations of MET II, but not those of the SPTM? Alternatively, how frequently are program requirements far below AMTE's recommendations? We focused first on programs that did not meet recommendations for methods courses and then on programs that did not meet recommendations for content courses. Because these recommendations vary by grade band and our earlier analysis found meaningful differences between Early Childhood programs and All Elementary programs and among credential types, we have disaggregated the data by grade band and by credential type.

Math methods requirements

Programs that did not meet AMTE's methods recommendations typically required half or fewer of the credits suggested in the SPTM, for both Early Childhood and All Elementary programs. However, as previously reported, Early Childhood programs were far more likely to meet these standards, with only 31.1% ($n = 33$ of 106) not meeting

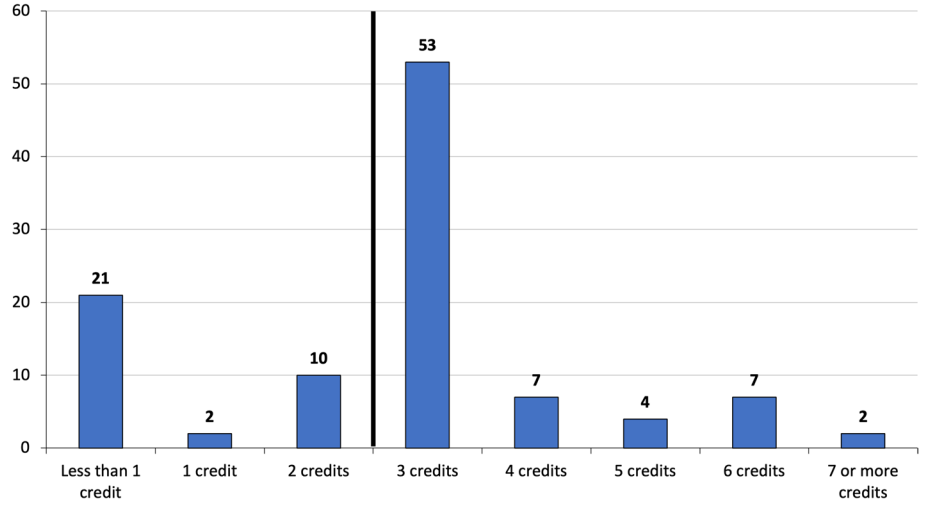

Fig. 5 Distribution of math methods credit requirements for early childhood programs. *Note:* AMTE's recommendation of 3 methods credits for early childhood programs is demarcated with a vertical line; programs to the right of the line meet or exceed AMTE's recommendations

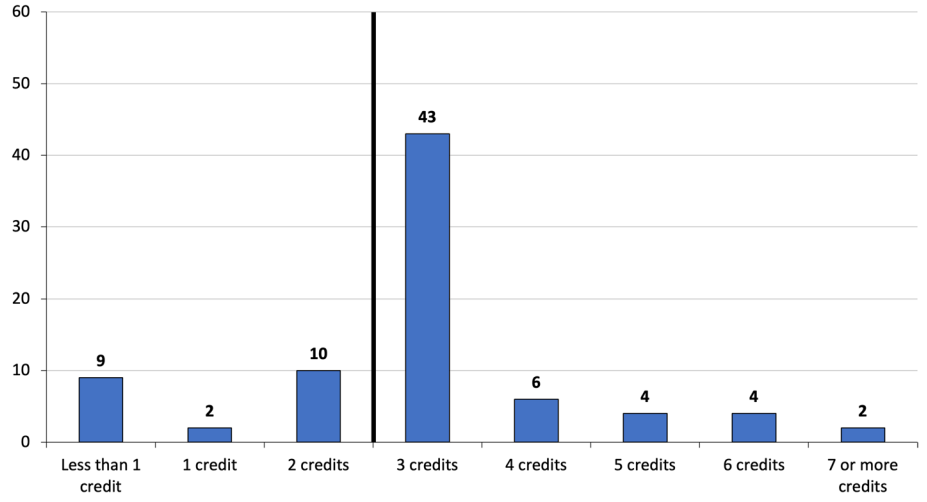

Fig. 6 Distribution of math methods credit requirements for Bachelor's-level early childhood programs

methods credit recommendations. Indeed, the median number of credits of mathematics methods for early childhood programs was 3, which is AMTE's recommendation. Within the 33 Early Childhood programs that fell below AMTE's recommendation, most ($n = 21$, 20.0% of Early Childhood programs) required no mathematics methods credits at all (see Fig. 5). Programs requiring no math methods courses may include a content-neutral methods course (e.g., pedagogical methods for early childhood), but such a course may not provide PSTs adequate opportunities to learn to teach mathematics.

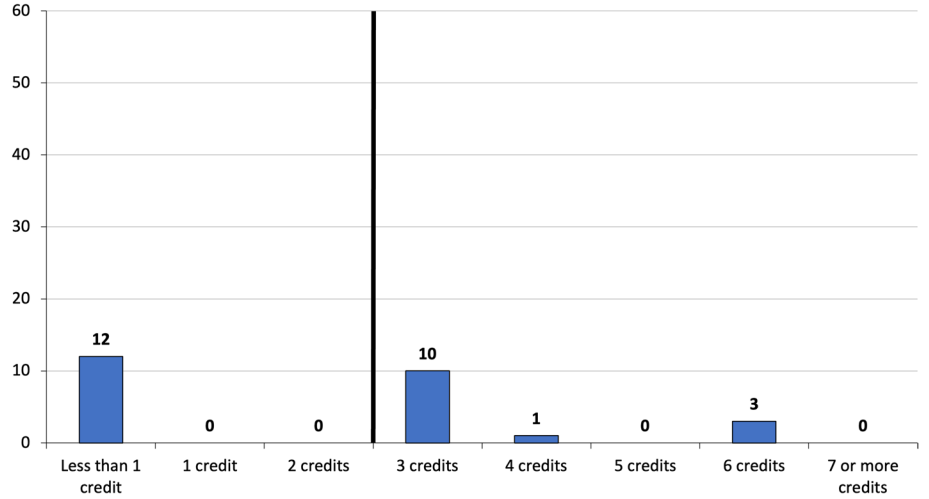

Fig. 7 Distribution of math methods credit requirements for Certificate and Master's-level early childhood programs

We disaggregated the data in Fig. 5 by credential type: Fig. 6 shows math methods requirements for Bachelor's-level Early Childhood programs, while Fig. 7 shows math methods requirements for Certificate and Master's-level Early Childhood programs. We combined the data for Certificate and Master's-level programs because they are typically of a similar length—one or two years, as opposed to a four-year bachelor's degree.

In general, Bachelor's-level Early Childhood programs are more likely than Certificate and Master's-level programs to meet AMTE's recommendations of 3 credit hours of mathematics methods courses. Indeed, nearly three-quarters (73.8%, $n = 59$ of 80; Fig. 6) of Bachelor's-level programs require at least 3 credit hours of methods, while about half (53.8%, $n = 14$ of 26; Fig. 7) of Certificate and Master's-level programs do so. Moreover, the Certificate and Master's-level programs that do not meet AMTEs recommendations ($n = 12$) each require less than one credit hour of mathematics methods courses.

For All Elementary programs, AMTE recommends 6 credits of methods courses; most All Elementary programs in our sample did not meet these standards (85.7%; $n = 324$ of 378). Many of these programs ($n = 194$, 51.3% of All Elementary programs) required approximately 3 credits of math methods ($3 \leq \text{credits} < 4$); the median number of credits required in All Elementary programs was 3, or half of the recommended number (see Fig. 8). That is, All Elementary programs, despite encompassing two grade bands of mathematics, typically only provide the methods courses recommended for programs encompassing one grade band (e.g., Early Childhood or Upper Elementary). Moreover, an additional 15.6% (n = 59 of 378) of All Elementary programs require less than one credit of math methods, with 58 (15.3% of All Elementary programs) requiring no math methods at all.[2]

[2] One quarter-system program required a single 1-credit course in math methods, which is the equivalent of two-thirds of a semester credit.

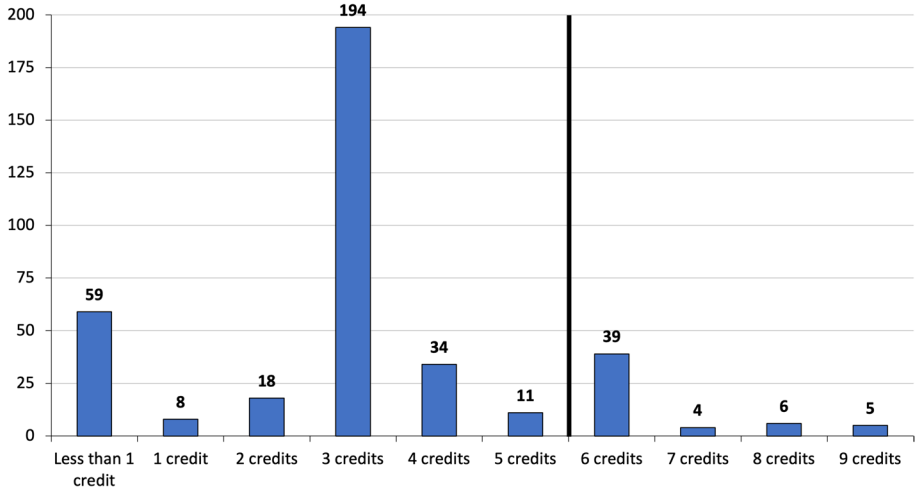

Fig. 8 Distribution of methods credit requirements for all elementary programs. *Note:* AMTE's recommendation of 6 methods credits for all elementary programs is demarcated with a vertical line; programs to the right of the line meet or exceed AMTE's recommendations

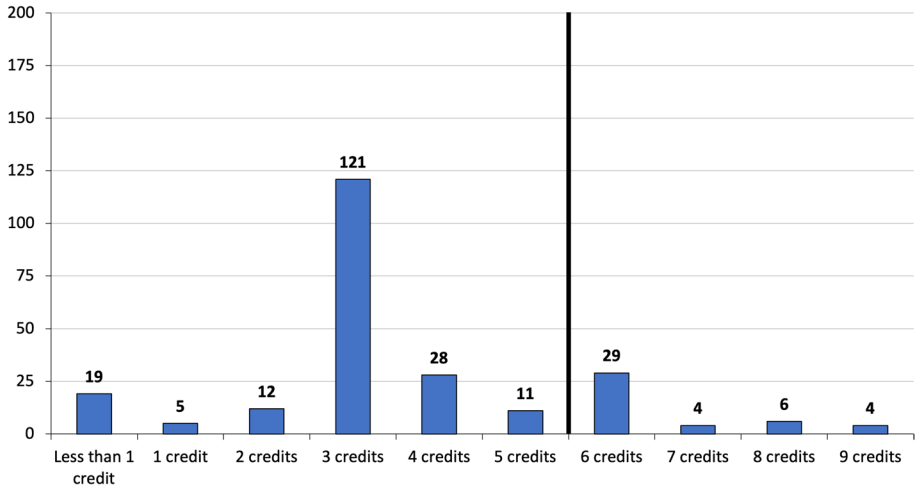

Fig. 9 Distribution of methods credit requirements for Bachelor's-level all elementary programs

In Figs. 9 and 10, we disaggregate the data in Fig. 8 by credential type: Fig. 9 shows math methods requirements for Bachelor's-level All Elementary programs, while Fig. 10 shows math methods requirements for Certificate and Master's-level All Elementary programs.

Similar to our findings for Early Childhood programs, the Bachelor's-level All Elementary programs are more likely than Certificate and Master's-level programs to meet AMTE's recommendations of 6 credit hours of mathematics methods courses. Indeed, 18.0% ($n=43$ of 239; Fig. 9) of Bachelor's-level programs require at least 6 credit hours

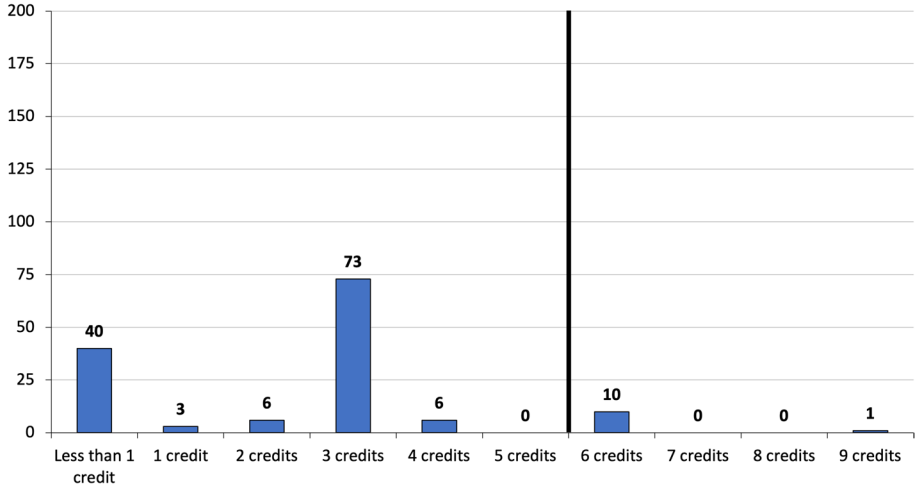

Fig. 10 Distribution of methods credit requirements for Certificate and Master's-level all elementary programs

of methods, while just 7.9% ($n=11$ of 139; Fig. 10) of Certificate and Master's-level programs do so. Moreover, more than a quarter of All Elementary Certificate and Master's-level programs (28.8%, $n=40$ of 139) require less than one credit hour of mathematics methods courses.

Math content requirements

For programs in both Early Childhood and All Elementary that did not meet AMTE's mathematics content recommendations, the modal number of credits required was less than one. These credit recommendations are vastly different for Early Childhood (3 credits) and All Elementary (15 credits). Early Childhood programs were again far more likely to meet the content recommendations (74.5%; $n=79$ of 106), with a median of 6 credits of mathematics content required. Only 27 programs (25.5%) fell below this threshold, as shown in Fig. 11. Of the Early Childhood programs that did not meet AMTE's content recommendations, most ($n=25$, 23.8% of Early Childhood programs) required no mathematics content credits at all. However, it is worth noting that the programs meeting AMTE's recommendations—shown on the right of the histogram—often far exceeded these standards, with many requiring the equivalent of two, three, or more semester courses.

We then disaggregated the data in Fig. 11 by credential type: Fig. 12 shows math content requirements for Bachelor's-level Early Childhood programs, while Fig. 13 shows math content requirements for Certificate and Master's-level Early Childhood programs.

Much like our findings for math methods requirements, Bachelor's-level Early Childhood programs are more likely than Certificate and Master's-level programs to meet AMTE's recommendations of 3 credit hours of mathematics content courses. In fact, nearly all of the Bachelor's-level Early Childhood programs require at least 3 credit hours of mathematics content (96.3%, $n=77$ of 80; Fig. 12)—with many requiring much more. Yet, few of the Certificate and Master's-level Early Childhood programs (15.4%, $n=4$ of 26; Fig. 13) do so.

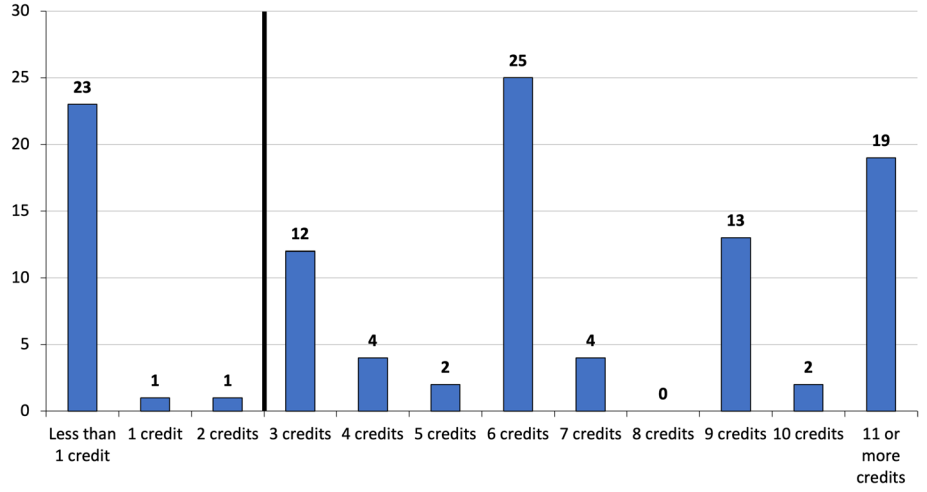

Fig. 11 Distribution of mathematics content credit requirements for early childhood programs. *Note*: AMTE's recommendation of 3 mathematics content credits for early childhood programs is demarcated with a vertical line; programs to the right of the line meet or exceed AMTE's recommendations

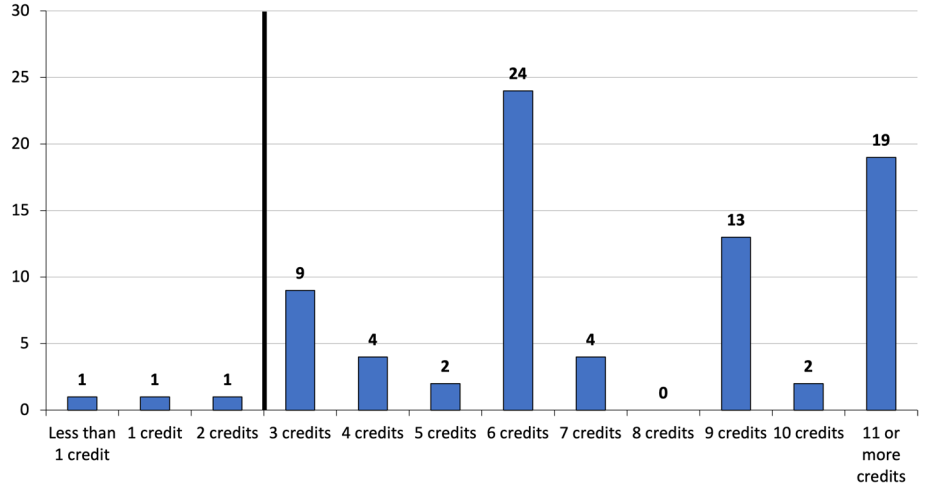

Fig. 12 Distribution of mathematics content credit requirements for Bachelor's-level early childhood programs

Programs for All Elementary grades were unlikely to meet AMTE's recommendation of 15 mathematics content credits; indeed, fully 91.5% ($n = 346$ of 378) did not (see Fig. 14), with a median of 6 credits of mathematics content required, the same number of credits as Early Childhood programs. Of the All Elementary programs that did not meet AMTE's recommendations, 40.4% ($n = 140$ of 346) required less than 3 credits of mathematics content, with 126 programs (36.4% of programs that did not meet the standard, 33.3% of all All Elementary programs) requiring no content credits at all. The remaining All Elementary programs that did not meet content standards are fairly evenly distributed, with half

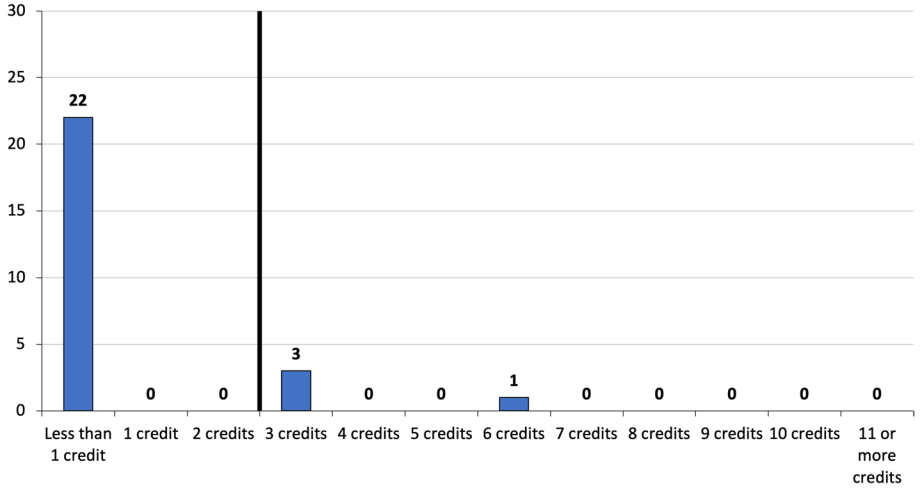

Fig. 13 Distribution of mathematics content credit requirements for Certificate and Master's-level early childhood programs

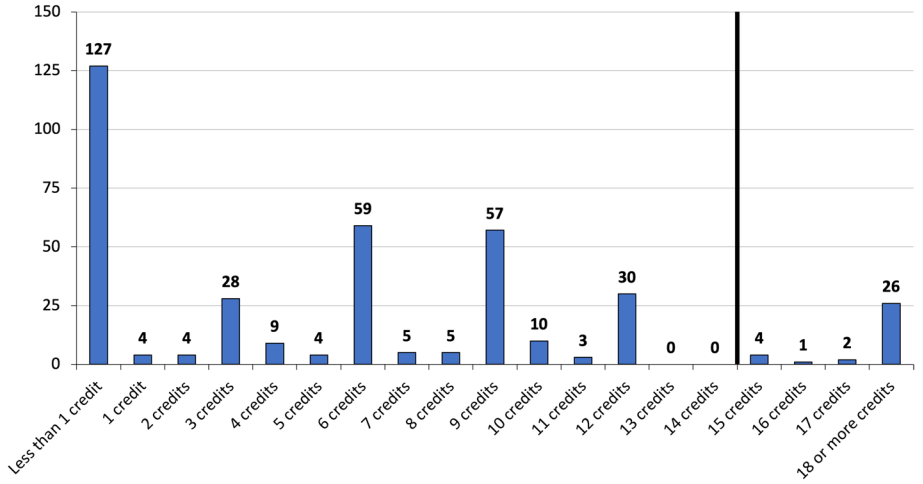

Fig. 14 Distribution of mathematics content credit requirements for all elementary programs. *Note*: AMTE's recommendation of 15 mathematics content credits for all elementary programs is demarcated with a vertical line; programs to the right of the line meet or exceed AMTE's recommendations

(50.6%, $n=175$ of 346) requiring between 6 and 11 credits. This is comparable to the Early Childhood programs—where 51.9% ($n=55$ of 106) required between 6 and 11 credits of math content—but AMTE's recommendations for mathematics content are much higher for All Elementary programs than Early Childhood programs. While All Elementary programs that did not meet AMTE's content standards were likely to require *some* mathematics credits, only a small number of these programs met the minimum requirements outlined in MET II (CBMS, 2012): 8.7% ($n=30$ of 346) required 12 credits.

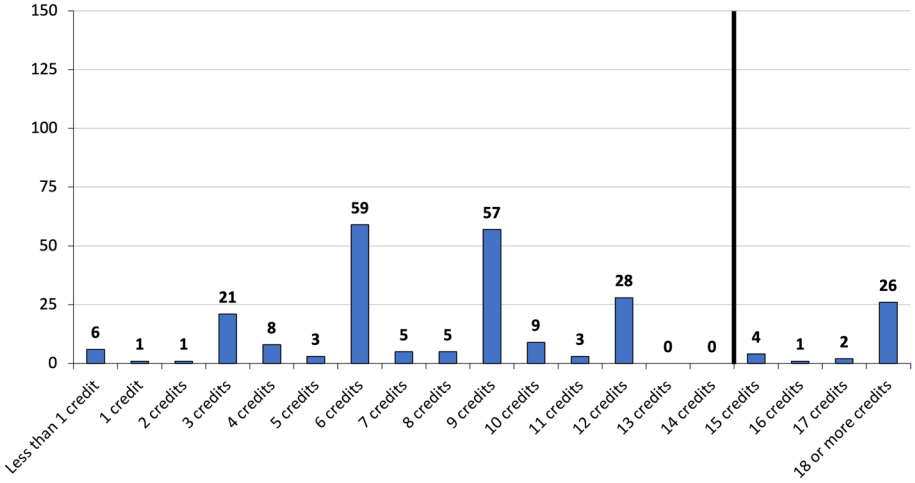

Fig. 15 Distribution of mathematics content credit requirements for Bachelor's-level All Elementary Programs

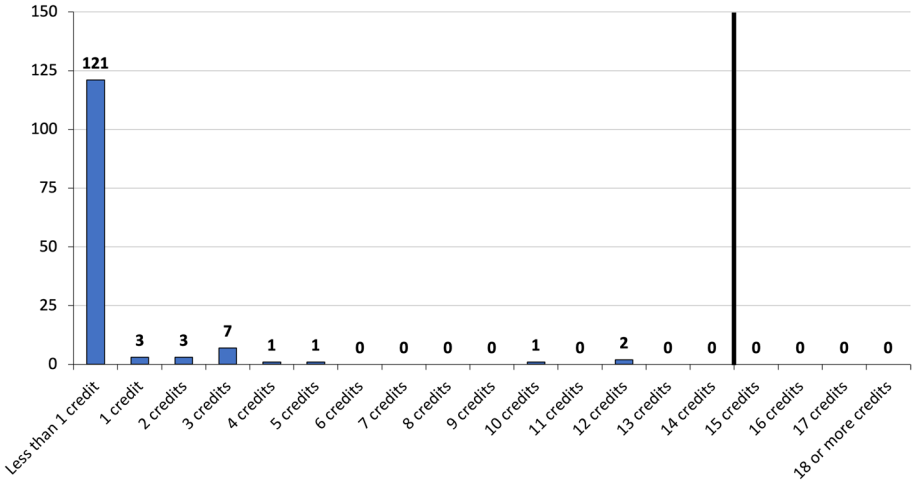

Fig. 16 Distribution of mathematics content credit requirements for Certificate and Master's-level all elementary programs

We disaggregated the data in Fig. 14 by credential type: Fig. 15 shows math content requirements for Bachelor's-level All Elementary programs, while Fig. 16 shows math content requirements for Certificate and Master's-level All Elementary Programs.

While few of the All Elementary programs in our sample meet AMTE's recommendations for mathematics content courses, those that do are all Bachelor's-level programs, representing 14% of the Bachelor's-level All Elementary programs (Fig. 15). None of the Certificate and Master's-level programs require 15 credit hours of mathematics content (Fig. 16). Even looking at the MET II recommendations—what the SPTM describe as minimum requirements (AMTE, 2017)—just 1.4% of Certificate or Master's-level All

Elementary programs ($n=2$ of 139) require 12 credit hours of mathematics content, while 26.3% ($n=63$ of 239) of Bachelor's-level All Elementary programs do so.

Overall, this analysis indicates that when elementary pre-service teacher education programs did not meet AMTE's methods or content credit recommendations, they often failed to do so by wide margins. The analysis also indicates that the type of program plays a meaningful role in how likely their requirements are to meet or exceed the SPTM, with Bachelor's programs more often requiring the recommended credits of mathematics methods and content courses, as compared to Master's and Credential programs.

Limitations

Our study has some important limitations. We collected data from institution websites and publicly available documents that described program requirements (e.g., student handbooks); the accuracy of these sources is subject to the frequency with which they are updated and maintained. Perhaps the largest limitation is that, by collecting program data from websites and other publicly available information, we can examine the number of credits of mathematics courses required by different programs, but we cannot see into the courses themselves. This can cut both ways: There may be mathematics content or methods courses that do not offer adequate learning opportunities, perhaps because they do not cover the topics recommended by AMTE or because they are taught in dehumanizing ways (i.e., instruction that induces further math anxiety or promotes limited beliefs about who can do math). Yet, there may also be courses that are labeled as content-neutral, but offer important opportunities to learn mathematics layered with how to teach mathematics. Furthermore, programs may provide important learning opportunities that fall outside of course requirements: electives, clinical placements, residency programs, and other professional learning opportunities may supplement PSTs' coursework.

Despite these limitations, the scope of our findings—specifically, that the majority of US teacher education programs require fewer mathematics methods and content courses than is recommended by major professional organizations (i.e., AMTE and CBMS)—suggest that this issue is widespread and serious. Next, we turn to discuss the implications of this study.

Discussion

The findings from our analysis have important implications for the field of elementary mathematics teacher preparation. Our initial motivation for this study came from our experiences as mathematics teacher educators, as we recognized that our own programs offered limited mathematics courses for elementary PSTs. Yet, we were unsure of how widespread this issue was: Did other institutions require more mathematics courses in their teacher preparation programs? Or was it common to require just a few credits of math content and methods?

In our investigation of teacher preparation programs across the US, we found that programs requiring limited mathematics content and methods courses are the norm. Our analysis estimates that nearly two-thirds of elementary teacher education programs in the US do not meet the recommendations set forth by AMTE for adequately preparing future

teachers to teach elementary mathematics. Moreover, we estimate that an additional one-fifth of programs fall short in either math methods or math content requirements. Importantly, these programs are not isolated to a small number of institutions: Approximately three-quarters of US colleges and universities do not have any teacher preparation program that meets AMTE's recommendations. Even in comparison with the more modest recommendations of MET II (CBMS, 2012)—that is, 12 credit hours of mathematics content for elementary teachers, with some additional credit hours devoted to mathematics methods—more than four-fifths of the programs in our sample fell short; this corroborates findings in prior surveys of mathematics content courses for elementary teachers (Masingila et al., 2012; Masingila & Olanoff, 2021). Furthermore, our findings are noteworthy precisely because our analytic grain-size—the number of required credits—was broad; it is likely that a closer examination of the content of the courses (and other program features) would reveal additional gaps in the scope and depth of elementary mathematics teacher preparation.

Yet, we must also keep the purpose of the AMTE recommendations in mind. They are, admittedly, aspirational; they offer a vision for what excellent mathematics teacher preparation requires in order for students in the US to achieve the ambitious goals of the Common Core (NGA, 2010) and other state standards. These aspirations may not be feasible. Since most elementary teacher preparation programs are targeted for generalist licensure—covering all content areas and all elementary grades—the AMTE recommendations may present a substantial challenge. If 21 credits of mathematics are recommended for learning to teach math, do elementary PSTs need similar amounts of coursework in other content areas, as well? Moreover, requiring 21 credits of math content and methods could create a substantial burden for Master's and Certificate programs, which typically last only one or two years; requiring similar coursework in multiple content areas may be impossible for such programs.

From an international perspective, however, it seems that the US has not adequately invested in teacher preparation. Nations like Finland and Singapore, with stronger and more equitable investments in the teaching profession, offer longer programs—requiring more courses to learn content and pedagogy—for pre-service teacher preparation (Darling-Hammond, 2017). Even if AMTE's recommendations seem overly ambitious for US teacher preparation programs as they currently stand, this study may indicate the need for additional investments in elementary teacher preparation. Ultimately, the overall pattern found in our data raises questions about the influence that independent organizations—like AMTE—can have over teacher preparation programs in countries like the US, where education policy is decentralized and where professional standards are recommendations, rather than requirements.

Given the importance of elementary teacher preparation, it is worth asking: Why don't programs offer PSTs more course-based opportunities to learn mathematics and to learn to teach mathematics? Several potential explanations exist, with implications for program design. Economic pressures—on teacher education programs as well as PSTs—disincentivize additional course requirements, regardless of the benefits. In many countries, higher education institutions compete for PSTs with alternative pathways to teacher licensure. While elementary education is by far the most popular focus for PSTs, teacher shortages have led to the proliferation of alternative certification routes that are faster and cheaper than traditional university-based programs (King & Hampel, 2019; Sutcher et al., 2016). Adding course requirements to university-based teacher education programs could increase either the time-to-degree or the overall cost of the program. Such changes could further drive students to routes that prepare them less thoroughly (Darling-Hammond et al., 2002).

In the US, there has been a shifting tide toward graduate programs, rather than undergraduate programs, to prepare future teachers; this recognizes the professional work of teachers as requiring training beyond a bachelor's degree and allows pathways into teaching for non-traditional students and those seeking a career change. However, our data show that Master's programs—despite their advanced level—were less likely than Bachelor's programs to meet AMTE's recommendations. Graduate programs are of shorter duration than undergraduate programs; keeping these programs to a single year has been proposed as a key strategy for addressing the growing teacher shortage (Carver-Thomas & Darling-Hammond, 2017). Yet, the time frame limits the number of courses students can take alongside clinical placements and other learning opportunities; adding courses for mathematics teacher preparation might necessitate eliminating courses in other important areas, such as literacy or science.

Furthermore, programs are designed to meet state-level certification requirements, not AMTE's recommendations. If states require few mathematics education courses, universities may not choose to exceed these expectations. Given the large number of programs in our sample requiring no mathematics methods credits (20% of Early Childhood programs, 15.6% of All Elementary programs) or no mathematics content credits (23.8% of Early Childhood programs, 33.3% of All Elementary programs), providing programs with this latitude can have drastic consequences for the preparation of future teachers of elementary mathematics.

Graduate programs typically negotiate the challenge of providing enough courses by relying on entrance requirements to fulfill content courses as prerequisites from undergraduate programs. However, these prerequisites are typically broadly construed (e.g., 6 credits of general mathematics) and do not specifically address content for teaching elementary mathematics. MET II (2012) emphasizes that courses such as college algebra, calculus, or liberal arts mathematics are not substitutes for developing knowledge of elementary mathematics. In other words, general mathematics requirements are unlikely to actually address AMTE's recommendations for content courses. As such, PSTs from graduate programs may have mathematics content courses on their transcripts, but still be underprepared to teach elementary mathematics. This may ultimately exacerbate the US teacher shortage; failing to adequately prepare PSTs for their work leaves them more likely to leave the profession (Darling-Hammond et al., 2002).

The pressures to prepare teachers at the graduate level—and to do so quickly and well—creates real tensions that require systemic design solutions. We suggest that one possibility is for higher education institutions to continue to create and promote pre-education undergraduate degrees that can serve as a more intentional pipeline for those entering graduate-level teacher education programs. Such pre-education undergraduate degrees could offer foundations for a number of education and human development professions that require graduate training, from teaching to social work. Content course requirements in such programs could be tailored to building robust pedagogical content knowledge and mathematical knowledge for teaching that will support them as future elementary teachers. Pre-education undergraduate programs could lead to a stronger focus on teaching methods and clinical placements in Master's-level and Certificate programs.

Within teacher education programs—whether graduate, undergraduate, or credential—our findings suggest that course requirements do not account for the number of grade levels elementary PSTs are being prepared to teach. Programs designated as All Elementary—which prepare PSTs to teach up to seven grade levels—typically had mathematics methods and content course requirements similar to Early Childhood programs, which prepare PSTs to teach three to four grade levels. We suggest that, regardless of *which* grades PSTs are

being prepared to teach, programs must consider *how many* grades of mathematical content and pedagogy PSTs are expected to learn. Teaching more grades demands more time to provide adequate opportunities to learn to teach students across those grades.

Finally, the pivotal role of state policies in shaping course requirements suggests it is a key lever for changing mathematics teacher preparation programs. Advocacy for additional requirements for teacher licensure or program accreditation at the state level could have wide-reaching effects, particularly in states where programs have been allowed to require no mathematics methods or no mathematics content courses. While analyses of state-level accreditation and licensure policies fell outside the scope of this study, we believe that research coordinating state-level policies and AMTE's recommendations would benefit the field in our ongoing efforts to adequately prepare future teachers of mathematics across all grades.

Conclusion

In this study, we found a widespread and systemic pattern in elementary teacher education: When analyzed with respect to the SPTM, most programs offer insufficient opportunities for PSTs to learn about mathematics and to learn to teach mathematics. This is an alarming issue, and it is undoubtedly complex. Changing the landscape of teacher preparation implicates many different stakeholders and entities, from state licensure boards and accreditation systems to individual institutions and programs. There is no simple solution; indeed, there are likely many different kinds of solutions that are appropriate for different contexts. But by examining the current state of elementary mathematics teacher education, we aim to shed light on this important issue. In order to adequately prepare elementary PSTs to teach math well, the field of elementary teacher preparation must make significant changes.

Finally, as we move forward to consider the possible changes appropriate for different contexts, we hope that our study can contribute to the international literature on elementary teacher preparation. Moreover, we invite scholars to share how changes have been implemented in the international contexts in order to inform policy decisions for change around the world.

Appendix

Public and private institutions by region

Region	Number of public institutions	Number of private institutions
Northeast	18	44
Midwest	28	49
South	54	53
West	24	21
Total	124	167

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