Examining preservice teachers' descriptions of the Standards for Mathematical Practice

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Abstract

The widespread adoption of the Standards for Mathematical Practice (SMPs) in state K-12 mathematics standards implies preservice teachers (PST) must understand these standards to be prepared, beginner teachers. To date, limited research has investigated PST understanding of the SMPs. This paper shares a study that examined which components of the Common Core SMP descriptions PSTs attended to in their own descriptions of the SMPs. Study findings indicate PSTs focused on broad overarching ideas or specific actions involved in SMP engagement depending on which SMP they were describing. Implications for teacher educators and standards authors are discussed.

Keywords: Preservice teachers, Standards for Mathematical Practice, CCSSM

1 Introduction

The Association of Mathematics Teacher Educators' (AMTE) state that beginning mathematics teachers should be able to "read, analyze, and discuss, curriculum, assessments, and standards documents" (AMTE, 2017, p. 3). One example of these standards documents is the eight Standards for Mathematical Practice (SMPs), initially put forth in the Common Core State Standards for Mathematics (CCSSM; National Governors Association for Best Practices [NGA], 2010). These SMPs (Table 1) describe ways of thinking about and doing mathematics that parallel how mathematicians engage in their work that all mathematics teachers should be developing with K-12 students. Even as states have revised their standards since their initial adoption of the CCSSM, these revisions have primarily focused on content standards with the SMPs remaining the same (e.g., New York State Next Generation Mathematics Standards). Further, the importance of developing students' mathematical thinking abilities was recently reinforced by Dykema and colleagues (2024), who argue that mathematical practices like mathematical modeling (SMP 4), thinking structurally (SMP 7), generalizing (SMP 8), and understanding quantitative relationships (SMP 2) should be the focus of K-12 curricula moving forward. Given the widespread and continued focus on the SMPs, it is clear the SMPs are standards that mathematics teachers should be able to "read, analyze, and discuss" (AMTE, 2017, p.3).

Table 1. *Common Core Standards for Mathematical Practice (SMP)*

SMP	Full Title	Abbreviated Title
SMP 1	Make sense of problems & persevere in solving them	Problem-solving
SMP 2	Reason abstractly and quantitatively	Quantitative Reasoning
SMP 3	Construct viable arguments & critique the reasoning of others	Argumentation
SMP 4	Model with mathematics	Modeling
SMP 5	Use appropriate tools strategically	Tools
SMP 6	Attend to precision	Precision
SMP 7	Look for and make use of structure	Structure
SMP 8	Look for and express regularity in repeated reasoning	Repeated Reasoning

Initial teacher education is one space where preservice mathematics teachers (PSTs) can do this reading, analysis, and discussion. Prior research has examined PSTs' understanding of the SMPs (Disney & Eisenreich, 2021; Matney et al., 2025) as well as how course learning opportunities can help PSTs learn what the SMPs are (Bostic & Matney, 2014; Kruse et al., 2017), what doing an SMP looks like (Max & Welder, 2020), and how to facilitate K-12 students' engagement in them (Cheng, 2017; Gurl et al., 2016). While findings from this prior research are useful, it is also limited, as much of the SMP-focused researched to date examines in-service teachers' SMP understandings (e.g., Bleiler et al., 2015; Bostic & Matney, 2014; Colen, 2019; Shelton et al., 2020). Thus, additional studies are needed to provide insight into how PSTs understand the SMPs (Matney et al., 2025). It is only with this insight that teacher educators can effectively plan and facilitate learning opportunities that support PSTs' developing understanding of the SMPs and their ability to address them within instruction; without this insight, it is unclear how the SMP understandings that PSTs develop during their initial teacher education programs will allow them to effectively develop students' mathematical thinking abilities, if at all. The study described here shares an analysis to help address this need. It shares which components of the CCSSM SMP descriptions PSTs attended to in their own descriptions of the SMPs. Study findings indicate PSTs focused on broad overarching ideas or specific actions involved in SMP engagement depending on which SMP they were describing. Implications for teacher educators and standards authors are discussed.

2 Relevant Literature

As noted, much of the SMP literature to date has focused on in-service teachers including their understandings and implementation of the SMPs (e.g., Bleiler et al., 2015; Bostic & Matney, 2014; Colen, 2019; Shelton et al., 2020). These studies indicate that it is challenging for teachers to make sense of the SMPs due to the abstract language used within the SMP descriptions alongside few specific examples of what doing them in different grade-levels and content areas looks like. The limited research examining PSTs shows similar challenges in understanding the SMPs. For example, Disney & Eisenreich (2021) found PSTs identified students' use of a teacher selected tool as evidence of SMP 5: Tools even though the CCSSM describes SMP 5 as when *students* select tools that are appropriate and useful for solving a given task. There were also repeated instances of PSTs considering the memorization of facts to be evidence of generalizing (SMP 8: Repeated Reasoning). In addition to illustrating some of the misunderstandings PSTs may have about the SMPs, these findings also suggest these misunderstandings may be grounded in the tension between the active, student-focused vision of learning mathematics described by the CCSSM and the traditional notions of teaching and learning mathematics (e.g., teacher-centered instruction, rote memorization) PSTs may have. While such findings are potentially useful to teacher educators, additional studies that identify common SMP-misunderstandings would better support teacher educators in designing learning opportunities that address these misunderstandings and the notions informing them.

Recent studies show that undergraduate courses can provide opportunities for PSTs to engage in and learn about the SMPs, however, there may be variability in which SMPs are included. For example, Max and Welder (2020) found that while all SMPs were addressed in most content courses for elementary PSTs, almost all instructors reported their attention to the SMPs varied; SMP 3: Argumentation was reported as the most addressed while SMP 6: Precision and SMP 8: Repeated Reasoning were addressed the least. Moreover, their analysis of course activities found that opportunities to engage in SMP 3 were limited to PSTs constructing arguments and did not include opportunities to critique the reasoning of others. Researchers examining opportunities for secondary PSTs have found similar results (Baldinger, 2015; Jung & Newton, 2018; Stohlmann et al., 2015). For example, Baldinger (2015) found that PSTs in an Abstract Algebra course primarily learned *about* the SMPs via instructor demonstration, but also had opportunities to *engage in* the SMPs. Across these opportunities, PSTs most frequently learned about/engaged in SMP 1: Problem-solving & Perseverance, SMP 3: Argumentation, and SMP 6: Precision. Baldinger noted that the nature of Abstract Algebra course content did not allow for engagement in SMP 4: Modeling. Moreover, her findings suggested that the SMPs are interconnected because PSTs' improvement in one SMP often related to another.

Other researchers have examined opportunities focused on specific SMPs, such as SMP 4: Modeling. For example, Jung and Newton (2018) and Stohlmann and colleagues (2015) found that PSTs' understanding of mathematical modeling aligned more closely with the CCSSM's description of modeling as using mathematics to solve complex, real-world problems, as opposed to using manipulatives or diagrams to model mathematical ideas, following opportunities to discuss the CCSSM description of SMP 4 and engage in modeling activities. These shifts in understanding did not result in students incorporating modeling into their teaching (Jung & Newton, 2018). While highlighting the potential effectiveness of SMP-specific learning opportunities, such findings also suggest that multiple opportunities are needed to develop PSTs' SMP understandings *and* teaching practice. Moreover, the limited PST-focused SMP research means it is unclear how opportunities focused on *other* specific SMPs can support PSTs' SMP understanding, if at all. Therefore, as previously noted, additional studies would better support teacher educators in designing effective SMP learning opportunities.

3 Methods

This article shares findings from a larger study focused on understanding how initial teacher education can support PSTs' developing understanding of the SMPs. This paper focuses on the question: *How are PSTs' SMP descriptions informed by the CCSSM SMP descriptions?*

3.1 Participants and Context

Participants include eight PSTs from across two sections of an undergraduate education course, with approximately 20 PSTs each, designed to familiarized PSTs with K-12 mathematics education policy and other topics related to mathematics education. In five two-week modules, PSTs were introduced to the CCSSM content standards and SMPs (NGA, 2010), the five strands of mathematical proficiency (Kilpatrick et al., 2001) and other instructional ideas (Table 2). SMP-related learning opportunities included reading and discussing the CCSSM SMP descriptions, PSTs solving authentic K-12 tasks and analyzing their work that of their peers for evidence of the SMPs, and PSTs reflecting on their growing understanding of the SMPs.

Table 2. *Course Module Overview*

Module	SMP	Course Topic	Strand of Proficiency
1	CCSSM & SMP Overview	Mathematical Identity	Productive Disposition
2	SMP 2: Quantitative Reasoning; SMP 6: Precision	Multiple Representations	Conceptual Understanding
3	SMP 7: Structure; SMP 8: Repeated Reasoning	Discourse	Procedural Fluency
4	SMP 3: Argumentation; SMP 5: Tools	Justification	Adaptive Reasoning
5	SMP 1: Problem-solving; SMP 4: Modeling	Cognitive Demand	Strategic Competence

Participant characteristics include two males and six females, two secondary PSTs, five elementary PSTs, and one Psychology major/Education minor with interest in school counseling. The author recognizes that the limited number of PSTs who consented to participate in the study is a limitation. However, given the limited SMP-research focused on PSTs, this study is a useful step forward in helping teacher educators gain insight into how PSTs understand the SMPs; these findings can be used to inform future studies with a larger number of participants. Moreover, the demographics of PSTs who consented to participate reflect the range of backgrounds and interests of PSTs typically enrolled in this course.

3.2 Data Collection

Data come from two course assignments, one completed at the end of module 3 (M3) and another completed at the end of module 5 (M5) (n = 16; two per PST); these assignments were a part of the course and would have been completed irrespective of the study. Assignment prompts asked PSTs to describe and provide evidence of their developing understanding of the SMPs including, a) how they would describe key SMP ideas, b) why the SMPs are important, c) connections between the SMPs and other course topics, d) examples of how they saw themselves or others doing the SMPs when completing mathematical tasks, e) how class activities have shifted their understanding of the SMPs, and f) remaining questions they had about the SMPs. All names used are pseudonyms.

3.3 Data Analysis

Analyses focused on PST responses to the first assignment prompt which asked how they would describe key SMP ideas for the SMPs addressed in recent modules. PST descriptions were first coded using an adaptation of Nardi et al.'s (2012) classification of warrants to capture the sources students drew upon when describing the SMPs. Nardi and colleagues (2012) offer seven different categories to identify the sources mathematics educators use to support claims: 1) a priori epistemological, 2) a priori pedagogical, 3) institutional curricular, 4) institutional epistemological, 5) empirical personal, 6) empirical professional, and 7) evaluative. These categories capture the influences of mathematics teachers' personal or professional experiences (empirical), personal views or beliefs (evaluative), curricular resources (institutional curricular), shared disciplinary practices (institutional epistemological), and established definitions and pedagogical principles (a priori epistemological and pedagogical). This study used an adaptation of Nardi et al's (2012) warrant classification to which policy classifications were added to capture the influence of the CCSSM content standards (policy-content) and SMP descriptions (policy – SMP), and the strands of mathematical proficiency (policy – strand). These additional classifications were created to capture PST attention to the policies documents guiding the course. See Stoddard (2022) additional information.

Next, using analytic methods from past studies which chunked the CCSSM SMP text into smaller components (see Baldinger, 2014; Olson et al., 2014), segments coded policy – SMP and the CCSSM SMP descriptions were similarly chunked and compared to determine similarities between them. Coded text for each SMP were then reviewed across all PSTs to determine the frequency for each code and to uncover themes regarding the different SMP components that PSTs attended to (Marshall & Rossman, 2016). Comparing frequencies of the different codes revealed that, depending on the SMPs, PSTs focused on broad overarching ideas or specific actions involved in SMP engagement.

4 Findings

4.1 Overarching ideas

Table 3 shows the total amount of times the different components from the CCSSM SMP descriptions were identified across all PSTs' SMP 1 and 4 descriptions. For SMP 1: Problem-solving & Perseverance, PSTs most frequently included the overarching ideas that problem solving entails non-routine situations that requires one to *make sense of problems* (n = 7) and engage in *planning* (n = 7) before trying to find a solution. This is illustrated in the SMP 1 descriptions of "deciding what the problem is" (Nora, M5) or "finding the meaning of a problem" (Lucy, M5). While some may consider PST attention to sense-making trivial given the full title of SMP 1 is "make sense of problems and persevere in solving them," the limited attention to *perseverance* (n = 1) shows that explicit inclusion in an SMP title is not in and of itself sufficient to capture PST attention. PST descriptions also showed limited attention to actions potential involved in this in sense-making such as considering *analogous problems* (n = 1), *creating representations* (n = 2), or *looking for entry points* (n = 1).

Table 3. *CCSSM ideas and actions present in PSTs' SMPs 1 and 4 descriptions*

SMP 1: Problem-solving	n	SMP 4: Modeling	n
Make sense of problem	7	Connecting math and the real world	9
Planning a solution path	7	Solve real world problems	7
Evaluate own work	6	Apply/use math in real-world contexts	2
Revise/change plan	3	Create representation of situation/problem	3
Create representation	2	Make assumptions	2
Look for entry points	1	Interpret results with respect to context	1
Analogous problems	1	Identify quantities	1
Persevere	1	Make sense of relationships to draw conclusions	1
		Example of modeling	1

PST descriptions of SMP 4: Modeling most frequently included the overarching idea of modeling as *connecting mathematics and the real-world* (n = 9). This is illustrated in the description of SMP 4 as "applying mathematics students already know to solve problems in everyday life" (Lucy, M5). This description closely aligns to the CCSSM description of doing SMP 4 as, "apply[ing] the mathematics they know to solve problems arising in everyday life, society, and the workplace" (NGA, 2010). We know such problems involve constructing solutions through iterative processes, determining appropriate quantities and parameters, making assumptions, and creating and revising a model (Garfunkel et al., 2016; NGA, 2010). Table 4 shows that few PSTs included these actions in their descriptions, with *making* *assumptions*, *identifying quantities*, and *making sense of relationships to draw conclusions* occurring minimally. Together these findings suggest that PSTs' understanding of SMPs 1 and 4 was primarily focused on the overarching ideas of what it means to engage in these SMPs with less attention to actions involved in doing them.

4.2 Specific action

In contrast to PSTs' focus on overarching ideas for SMPs 1 and 4, PST descriptions of SMPs 3 and 6 show attention to a specific action for doing each SMP. This is evident from the frequencies of the different components from the CCSSM SMP descriptions identified across all PSTs' SMP 3 and 6 descriptions appear in Table 4. For example, the CCSSM describes SMP 3: Argumentation as a bidirectional practice that involves "give and take." One "gives" by constructing and sharing an argument with others, and "takes" by listening to and making sense of the arguments of others. Table 4 shows that PSTs focused on the "give" aspect by largely focusing on students *communicat[ing] their own solution method or justification to others* (n = 11).

Owen's description illustrates this:

> Watching elementary students engaging in SMP 3 means we would observe them talking to their peer about how they were able to add 21 + 35 using ten blocks, while secondary students would be seen justifying how they know the intercepts of a polynomial equation by showing an equation and line graph to show where the line intersects the $x - axis$ based upon the polynomials in the equation. (M5)

Actions involved in the "take" aspect of SMP 3 such as *listening to others*, *asking clarifying questions* or *discussing* and *critiquing the arguments of others* were found sparingly (Table 4). These findings suggest PSTs understood SMP 3: Argumentation as a unidirectional practice focused on the production of arguments.

PSTs' SMP 6: Precision descriptions also focused on *communication* (n = 14), namely that doing SMP 6 means to communicate precisely *about* mathematics. This includes communicating generally about mathematics, but also how definitions, mathematical language, units, and accurate calculations supports precise communication (Table 4). For example, Lucy stated, "when students communicate precisely to others, such as in a group discussion where the students give carefully formulated explanations to each other, using definitions, to reason" (M3). This description parallels the CCSSM which explicitly describes precise communication, including the formulation of clear explanations and use of definitions, as part of SMP 6.

The CCSSM *also* describes SMP 6 as being precise when *doing* mathematics via the capacity to "calculate accurately and efficiently, express numerical answers with a degree of precision appropriate for the context of the problem" (NGA, 2010). However, only two PSTs referred to calculations in their descriptions, with one PST including accurate calculations as an aspect of precise communication. Only Jack considered calculations separate from communication, claiming, "SMP 6 is about being precise and checking your work for mistakes, seeking the right answer ..." (M3). No PSTs included the appropriateness of precision for the context of the problem. These findings suggest that PSTs largely considered SMP 6: Precision to be focused on precise communication *about* mathematics, with limited attention to the role of precision when *carrying out* mathematical processes or calculations. Alongside their SMP 3 descriptions, these findings suggest that PSTs' understanding of SMPs 3 and 6 was primarily focused on one action for doing each SMPs, with minimal attention to the multiple different actions involved in each.

Table 4. *CCSSM ideas and actions present in PSTs' SMP 3 and 6 descriptions*

SMP 3: Argumentation	n
Communicate solution/justification to others	11
Definitions	4
Mathematical language	3
Explain reasoning	3
Examine claims	1
Correct calculations	1
Units	1
General	1
Grade-level appropriateness of arguments	6
Justify	4
Example of engagement	3
Concrete referents	2
Create diagrams	1
Listen to other	3
Identify mistakes/flaws	2
Critique others' ideas/solutions/justifications	2
Compare arguments	1
Ask clarifying questions	1
Make conjectures	1
Discuss others' solutions/justifications	1
Use definitions and established information	1
Analyze problem	1
Respond to others	1

SMP 6: Precision	n
Communication	14
Definitions	4
Mathematical language	3
Explain reasoning	3
Examine claims	1
Correct calculations	1
Units	1
General	1
Label graphs	2
Units	2
Correct calculations/answer	1
Clear work	1
Contextual meaning	1

4.3 Ideas and actions

For the remaining four SMPs, PST descriptions showed attention to both ideas and actions, however, PST attended to a smaller number of different components overall. Totals for the different components from the CCSM SMP descriptions identified across all PSTs' descriptions of the SMPs 2, 5, 7, and 8 appear in Table 5. Comparing Table 5 to previous tables shows that PSTs attended to a smaller number of total components for these SMPs compared to those previously discussed.

Table 5. *CCSSM ideas and actions present in PSTs' SMPs 2, 5, 7, and 8 descriptions*

SMP 2: Reasoning	n	SMP 5: Tools	n
Decontextualize	4	Use tools	6
Contextualize	3	Identify appropriate tools	5
Make sense of quantitative...	3	Examples of tools	4
Create representations	3	Purpose of tools	2
Units	1		
Flexible use of operations	1		

SMP 7: Structure	n	SMP 8: Repeated reasoning	n
Identify underlying structures...	5	Identify patterns/repetition	10
Examples of using structure	5	Generalize	6
(De)composition	4	Reasonableness of results	3
Shift perspectives	2	Examples of repeated reasoning	2
		Determining shortcuts	2

While PST descriptions of the previously discussed SMPs included a wide range of overall components ($\overline{x}$ = 9) but high frequencies for 1-2 of them, their descriptions of the remaining SMPs included a smaller range of overall components ($\overline{x}$ = 4.75) with relatively similar frequencies for these components. For example, PST descriptions of SMP 2: Quantitative Reasoning included the ideas of *decontextualize* (n = 4), *contextualize* (n = 3), *make sense of quantitative relationships* (n = 3), and *create representations* (n = 3) with similar frequencies. Alice's description illustrates how PSTs included multiple components within their descriptions:

> When students engage in SMP #2, "reason abstractly and quantitatively", they gain the ability to "decontextualize" a situation by using place fillers to represent quantities or separating the pieces of the problem from their original meaning. They also gain the ability to "contextualize" the results they found, turning them from an abstract representation of words or numbers into an answer that clearly fits the problem. SMP #2 also involves making sense of quantities and how they relate to each other and creating a coherent representation of a problem (M3)

Here, Alice includes the ideas of contextualizing and decontextualizing, what doing them would look like, and making sense of quantities and creating representations. Similar attention to different components occurred for both SMPs 7: Structure and 8: Repeated Reasoning (Table 5), which each include aspects of "looking for" and "making use of" mathematics.

5 Discussion

Given PSTs and in-service teachers often struggle to understand the SMPs after participating in opportunities explicitly focused on learning about them (Bleiler et al., 2015; Colen, 2019), study findings are promising. They suggest that opportunities to read, discuss, and experience the SMPs during coursework can support PSTs in developing an initial understanding of them. This is especially promising as PSTs' prior learning experiences often do not reflect the vision of mathematics described by the SMPs. For example, PSTs often think of problem-solving as a procedural means to finding a solution (Son & Lee, 2021) rather than the process of grappling with non-routine problems (NGA, 2010). PSTs have often experienced traditional, teacher-centered instruction (Ball, 2000; CBMS, 2012; Seaman

& Szydlik, 2007), such as being told which tools to use rather than allowing space for student choice and exploration (SMP 5; NGA, 2010). Given these prior experiences, taken alongside the challenging CCSSM SMP descriptions, it makes sense that PST descriptions focused on a limited number of SMP components. Further, they highlight the importance of SMP-focused learning opportunities within initial teacher education. Specifically, the SMP components PSTs did focus on provide teachers educators with ideas for how learning opportunities can build upon each other. For example, given PST focus on the overarching idea of SMP 1: Problem-solving & Perseverance as solving problems that require sense-making and planning, subsequent opportunities could leverage this understanding by explicitly focusing on actions that support such sense-making and planning, such as considering analogous problems (NGA, 2010). Doing so would not only further develop PSTs' understanding of SMP 1 but also provide additional opportunities for PSTs to develop their problem-solving capabilities and experience the active mathematics they should facilitate in their future classrooms (CBMS, 2012).

Increasing explicit attention to SMP ideas and actions are one change that I (the author of this paper) have made after reflecting on the findings shared here. Now, throughout my mathematics education course, I have started explicitly telling PSTs when a task addresses specific SMPs, and then ask them to explain, in their own words, why that is the case. We then have small or whole class discussions that make clear the links between the actions they engaged in when solving the tasks to the SMP descriptions. When PSTs work on solving problems, I explicitly acknowledge the strategy of using the solution to a previous problem when PSTs are struggling to solve additional problems (e.g., use four given numbers to create 10 unique number sentences equaling 1-10; SMP 1); when PSTs state a task entails SMP 4, I ask them to explain how the task involves a messy real-world problem and to describe the assumptions they had to make or quantities they had to identify; when carrying out calculations, we discuss if/when an approximation is "good enough" based on what we are trying to figure out (e.g. is being within 10,000 miles sufficient when calculating the distance between stars?; SMP 6). In my mathematics education technology course, we regularly come back to the idea that while using technology to enhance instruction can support student engagement in many SMPs, using technology is not sufficient for students to be engaging in SMP 5 as that requires *students* to identify appropriate tools. Anecdotally, I can share that while PSTs still leave my courses with a partial understanding of the SMPs, they do appear to have a better understanding of the ideas and actions entailed in them. Future research should examine how PST understanding of the SMPs progresses as they experience different learning opportunities. These findings would provide valuable insight into how teacher educators could effectively plan SMP-focused learning opportunities. While single, small studies such as this one, have limitations, these findings are also potentially useful to standards authors and those who create supplemental resources and professional learning opportunities. Seeing which components of the CCSSM SMP descriptions were (not) attended to sheds light into which aspects of the SMPs can be easier/challenging for teachers to understand or where addition examples or rephrasing may be needed to make ideas or actions clearer. For example, the first five sentences of the CCSSM SMP 3 description focus on the construction of arguments; it does not refer to the "take" aspect of SMP 3 until the sixth sentence. Based on the findings shared here, a revision in the first sentence that makes the bidirectional nature of argumentation clear would be beneficial (e.g., mathematically proficient students use established definitions, logical statements, and (counter)examples, when creating their own arguments as well as making sense of arguments from others). Alternatively, including connections between the SMPs and specific content standards can help illustrate what each SMP "looks like" in different grade-levels (see New York State Education Department (2017) as an example).

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