SCHOOL MATHEMATICS ARTICULATION: CONCEPTUALIZING THE NATURE OF STUDENTS' TRANSITIONS (AND TEACHERS' PARTICIPATION IN THEM), K–16

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Students experience a variety of challenges as they move from one level in school to the next. In this session, we consider and discuss two central questions related to students' progressions through their mathematical experience, particularly at transitions roughly characterized as elementary to middle school, middle school to high school, and high school to post-secondary: What are the key dimensions/aspects of such transitions? What kinds of system-level responses address students' issues with transitions, particularly when they are problematic? We discuss research and practice related to students' challenges and the nature of system-level responses to various aspects of these school mathematics transitions, including mathematical content, curriculum, students' dispositions, classroom teaching practices, and school structures. Characteristics of selected strategies and programs are discussed and questions for further research are presented.

If students' motivation to learn mathematics, attitude toward mathematics, and interest in mathematics tends to decline as students progress through levels of education (Middleton & Spanias, 1999), then it is worthwhile to look more closely at how students experience school mathematics over time. Additionally, concerns have been expressed about the shortage of qualified workers for careers in mathematics, science, engineering, and technology (National Science Board [NSB], 2006) and the mathematical demands of informed civic engagement. Although we recognize that there are many fulfilling professional paths outside of STEM fields, it is important to consider how the accumulation of students' school mathematics experiences over time could inform their career choices and their relationships with the discipline of mathematics. If students choose not to engage further in mathematics beyond their required school experience, ideally they would make this choice because they prefer another option, not because their school experiences have taught them that mathematics is an intellectual and practical activity to avoid.

This paper addresses school mathematics articulation in terms of students' experiences as they move through school – from kindergarten through college. The study of students' progressions through levels of education provides insights about what we know and don't know about being a mathematics learner at various points in time in students' lives. We summarize research findings from some select studies to describe some transition issues as students move from (a) elementary school to middle school, (b) middle school to high school, and (c) high school to post-secondary experiences. To provide some conceptual clarity for the study of students' progressions through levels of education, we ask, "What are some of the aspects and dimensions of students' transition experiences as they move through their schooling?" To address this question, we will discuss various conceptualizations of students' transition experiences across school settings, such as: factors in school mathematics settings that can change over time, student-level factors that could indicate variations in their "transition" experiences, and conceptual lenses for viewing these factors (person-environment fit, what counts as a "mathematical transition," boundary-crossing, and rite of passage). We follow this discussion with the question, "What kinds of system-level responses address transition issues?" In response, we describe a few promising system-level responses to describe possible efforts to support students as they progress through mathematics programs over time. Finally, at the end of the paper, we explore promising possibilities for future research on students' transitions.

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Focus on Students' Experiences as They Move through School Settings

One of our premises in this paper is that students' experiences as learners of mathematics as they progress through school are important to understand and support. In addition to learning mathematics content, students are *becoming* mathematics learners as they move through school settings:

> As they [students] are compelled to sit in a mathematics classroom for a significant period of their school life, they come to learn how to participate in that context – they learn when to respond, when to resist, how to appear busy but avoid work. They learn how to cope with the embarrassment, the joy, the cajoling. They learn how the actions in the classroom have meaning and how some of the actions of teachers, texts and students take on substantially different meanings for themselves and others. They learn how to *be* a mathematics student. They develop a sense of who they are as learners within this context, a context which may be very different from other subjects within the school context and beyond the school context. (Boaler, William, & Zevenbergen, 2000, p. 3)

In this manner, we foreground the study of students' identities, as some have argued that "…learning and a sense of identity are inseparable: They are the same phenomenon." (Lave & Wenger, 1991, p. 115). Although our perspective does not equate learning and identity development, we highly value identity development as a significant outcome of students' school mathematics experiences, in addition to learning academic content. As students move through school settings, students develop their beliefs and practices as learners of mathematics and develop affiliations (or not) with the subject matter. Understanding students' experiences as a process of identity development is a way of conceptualizing learning. According to Wenger (1998), learning occurs through participating in communities of practice. Participating involves not only thinking and acting, but also developing increasingly central membership within communities. From this perspective, learning "changes who we are by changing our ability to participate, to belong, to negotiate meaning" (Wenger, 1998, p. 226).

What students learn—the ways students come to participate, come to view themselves, and come to view mathematics—is situated within opportunities to participate, and opportunities to participate are likely to vary as students move across school settings. School settings can be considered to be "facilitating contexts" (Grootenboer & Zevenbergen, 2008, p. 245) in which students have opportunities to develop relationships with mathematics. We recognize that opportunities to participate in school experiences may change as students move from one classroom to another. However, in this paper we focus on changes that can occur between grade bands—moving from elementary school to middle school, middle school to high school, and high school to other post-secondary experiences. An assumption in work on students' school transitions is that there are often more differences in mathematics teaching and learning between school buildings than within them and that these differences have implications for students' experiences.

We acknowledge that structures of school settings vary within the United States and also can differ between the U.S. school system and those of other North American nations. For instance, within the U.S. structure of elementary and middle schools, there are various configurations. Students may attend schools that include kindergarten through eighth grade on the same campus. Another structure involves schools constructed by grades K–5 on one campus and grades 6–8 on another campus. Still other configurations include grades K–6 on one campus and grades 7–9 on another (with high school starting at grade 10 rather than grade 9). For the purposes of this paper, we consider "elementary school" to encompass kindergarten through fifth grade, "middle school" to address grades six through eight, and "high school" to include grades nine through twelve. These demarcations follow the grade bands described in the *Principles and Standards for School Mathematics* (NCTM, 2000).

There may be an embedded assumption in work on school articulation and transitions across school settings that students remain in a particular school setting or school district for an extended period of time. We recognize that students may be mobile even during a particular school year. According to recent data (US GAO, 2010), 11.5 percent of K–8 schools have high rates of student mobility, such that more than 10 percent of students left by the end of the school year. These schools also had higher percentages of students who were low-income, English language learners, and received special education. However, we

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believe that the conceptual lenses and the transition issues affecting students discussed in this paper could be applied to some degree to students moving into new schools or new classrooms at other points in time.

Experiencing transitions involves navigating change, such as changes in approaches to mathematics teaching and curriculum between school buildings. In our effort to understand school mathematics articulation (or lack of it) over time, we do not believe that it is entirely possible or necessarily desirable to eliminate the changes that students experience. A perfect alignment of experiences over time is not possible or even ideal. Rather, we hope to consider the kinds of changes students might experience, whether students are aware of these changes and how they might respond, how to support students in navigating changes between school settings over time, and whether the changes that students encounter are purposefully created or occurring haphazardly.

The four authors of this paper collaborated because of our different experiences with scholarship around students' school mathematics transitions. Amanda and Jack worked together, with a number of other scholars, on the Mathematical Transitions Project [MTP]. Funded by the National Science Foundation (Jack Smith, Principal Investigator), our work in MTP investigated students' experiences as they moved from middle school to high school and high school to college when the mathematics curriculum materials shifted from either reform to traditional or traditional to reform (cf., Smith & Star, 2007; Star & Smith, 2006; Star, Smith, & Jansen, 2008; Jansen, Herbel-Eisenmann, & Smith, in press, 2012). Cathy and Janie were involved with writing a series of articles for *Teaching Children Mathematics* (Schielack & Seeley, 2010), *Mathematics Teaching in the Middle School* (Brown & Seeley, 2010), and *Mathematics Teacher* (Hull & Seeley, 2010) about students' experiences as they move from one level of education to another. This paper is an opportunity to synthesize and share what we've learned and to encourage mathematics educators to do more to consider how to understand and support developing students in the context of moving across school settings.

Conceptualizing Students' School Mathematics Transitions

Research on students' school mathematics transitions can be conducted from a range of perspectives. There can be a focus upon (1) the *internal* experiences of students, (2) the success (or not) of particular students in "moving along" as judged by *external* standards (grades, course-taking, etc.), (3) the success (or not) of institutions in supporting *aggregate* student success over time, (4) the effects of curriculum or teaching practice as they *correlate* to students' experience (internal) and/or success (external). To explore some of these foci, we share a representation that highlights some of the main factors in school mathematics settings that could either change or remain consistent over time and student-level dimensions that could indicate variations in their "transition" experiences (Figure 1).

We wanted this figure to display four temporal stages in time or grade bands (elementary years, middle school years, high school years, and post-secondary years of college and/or career). Also, we wanted to highlight a few factors in the school settings as well as student-level dimensions (both internal and external). The central column (large arrow) lists important student-level dimensions, such as learning, achievement, dispositions, patterns of working, and identity/direction. These dimensions could be relevant for students at any point in time. The ovals represent factors in school settings that may influence students' at any point in time and that could influence or shape any of the student-level dimensions. Figure 1 highlights some of the complexities of students' transitions across school mathematics programs, as changes along any of these factors in school settings or changes in any of the student-level dimensions could be significant to students in their experiences with school mathematics.

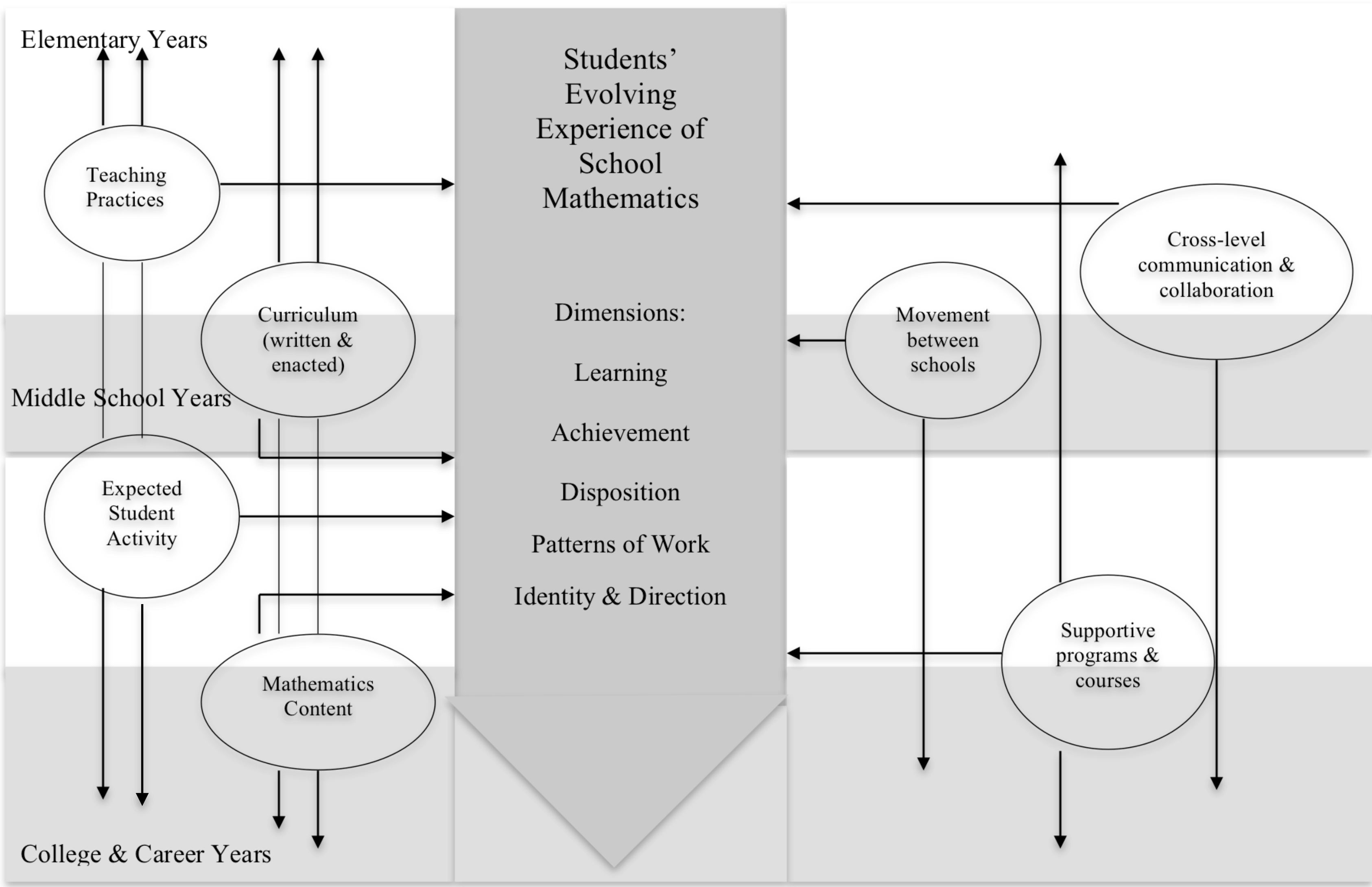

Figure 1: Visualizing students' transitions and the factors that shape them

Aspects and Dimensions of Issues in Students' Transitions

We wrestled with the order through which to present students' experiences over time. In the spirit of backwards design (Wiggins & McTighe, 2005), we considered starting our discussion of transition issues with post-secondary experiences (college and careers) and working back to earlier stages of schooling. This approach would have affording reflecting upon where students could land and working backward to support their successful journeys. Alternatively, we could begin with elementary school and move forward, because this timeline aligns with how students experience the accumulation of school mathematics experiences. After much discussion, we chose the latter option, as (for one reason) it is such a familiar frame for the issues that we consider.

Below, we share findings from a few select research studies. These studies provide insight on some conceptual lenses that have been used to understand the nature of students' transition experiences as they move across school settings: stage- or person-environment fit, boundary-crossing, and rite of passage. We present each of these conceptual lenses as we discuss the grade band of students or level of transition that the researchers studied. However, we do not mean to suggest that the conceptual lens should be used only with this grade band. Rather, we believe that these conceptual lenses could provide insight at any transition period, so lenses used previously to understand the transition from elementary school to middle school could also be useful for studying other transitions, such as the transition from high school to college (or to other post-secondary experiences). Other conceptual lenses that are useful for understanding students' experiences will be presented later in the paper.

The projects we discuss also highlight transition issues that students might experience as they move through school over time. We selected these studies because they highlighted ways to see interactions between dimensions of students' school mathematics transitions and system level responses, as many other studies report outcomes rather than offering explanations about why students might experience these outcomes.

Elementary School to Middle School

Schielack and Seeley (2010) previously summarized some of the issues that students often experience when moving from elementary into the middle grades mathematics. They described a student-level dimension: decreases in achievement in mathematics over time. Prior research suggests that, in general, students experience significant declines in academic achievement as they move from elementary school to middle school (Alspaugh 1998). They also highlighted factors in school settings, such as surface and substantive differences in curriculum materials, the variance in instructional approaches between settings, changes expectations for students' work, and increased difficulty in content. Some of the surface level features in the curriculum materials include change in color schemes, word density, font size, frequency of word problems or computational items in exercise sets. More substantively, the curriculum materials generally differ with respect to the types of representations used. For instance, elementary school mathematics textbook representations may be large and spacious (e.g., use of area models to represent fractions), and middle school mathematics textbook representations often using more symbolic and compact representations (e.g., linear models or number lines to represent fractions). Instructional approaches often vary in the degree to which teachers enact direct instruction and position students as receivers of knowledge or whether teachers encourage open exploration in which teachers act as facilitators. Schielack and Seeley (2010) acknowledge that these differences in curriculum or instruction could be reversed at the different grade levels. Changes in expectations for students' work in middle school include increases in the amount of independent work, including homework.

One conceptual lens that researchers have used to view students' experiences as they move from elementary school to middle school is the *stage-environment fit* perspective, which focuses on the degree to which students' developmental needs are met by the structures and practices of schooling. Foundational research on adolescent development (outside of mathematics education) has conceptualized students' experiences in the context of educational change in terms of fit between students' developmental needs and the school environment. This line of research addresses changes in adolescents' motivation over time as they move between school buildings. Declines in student motivation have been explained as a lack of a

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stage-environment fit (or a mismatch) (Eccles et al., 1993, following Erikson [1968]). "[R]esearch has found that academic declines in interest and self-concept are a function of the mismatch between the school environment and the adolescent" (Zarrett & Eccles, 2006, p. 17). A stage-environment fit is the quality of the match between the developmental needs of adolescents and the nature of the learning and social opportunities afforded to them. From this perspective, declines in students' motivation are not conceived as student deficits but as results of misalignment between students' needs at their stage of development and the learning and social opportunities afforded to them in their school experiences. Alternatively, students' motivation could remain strong or improve if there exists a fit between the student's needs and his or her experience in school.

Studies of the transition from elementary school to middle school reveal some examples of stage-environment mismatches (e.g., Eccles et al., 1993; Roeser, Eccles, & Sameroff, 2000; Wigfield, Eccles, & Roderiguez, 1998). The move toward ability grouping in the transition to middle school emphasizes social comparison at a time of heightened self-focus for adolescents. If teacher control increases and students' choices decrease in middle school, this conflicts with adolescents' increasing needs for autonomy. If teachers become more distant in their interactions with students in middle school, this may conflict with an adolescents' need to foster stronger relationships with adults outside the home.

Transition studies often provide insight at more of a top level, such as why students would continue to engage or not in school generally. However, there are some noteworthy exceptions. Roeser, Eccles, and Sameroff (2000) found that when middle school students perceived their school's curriculum to be meaningful, relevant to their lives, and supportive of their autonomy, they also expressed higher academic competence and higher academic value. Additionally, Midgley, Feldlaufer, and Eccles (1989) found that, during their transition into middle school, students who perceived lower degrees of support from their new mathematics teachers also reported lower intrinsic values for mathematics. More troubling, these findings were stronger for lower achieving students.

Looking back at our representation in Figure 1, these studies highlight particular factors in school settings and student-level dimensions. A move toward ability grouping indicates an example of change in the structure of the mathematics program that students experience. A more distant teacher-student relationship, reduced teacher support, and an increase in teacher control represent changes in instructional practices. An example of curricular factors was the degree to which the curriculum was perceived to be meaningful and relevant. These studies varied in terms of whether the factors in the school setting were perceived by students (self-reported) or observed by researchers. Student-level dimensions described were their reflections upon their identities (heightened attention to self, need for relationships with adults outside of the home) and disposition (need for autonomy, sense of competence, high value for academics).

Middle School to High School

As students move from middle school to high school, some of the factors in school settings and student-level dimensions occur again for students, and additional factors and student-level dimensions are incorporated for others. Brown and Seeley (2010) describe a range of factors in school settings and student-level dimensions that often change as students move from middle school into high school. Regarding school factors, they identified potentially insufficient alignment of mathematics instruction and curriculum materials across grade bands, specific issues with mathematics content in high school (e.g., mandatory Algebra I), and problems that could occur if high school teachers construct students as being "unmotivated" rather than trying to understand what they can do to motivate students. They also describe student-level dimensions, particularly decreases in achievement that seem to occur if students experience lack of alignment in curricular or instructional approaches (differences in the degree to which the mathematics programs are problem-centered and evoke sense-making or focus on teacher-directed procedural instruction). As we review some of the prior research on students' transitions into high school mathematics programs, we describe three conceptual lenses: person-environment fit, defining the nature of a mathematical transition, and boundary crossing.

Person-Environment fit. The person-environment fit conceptual lens is a variation on stage-environment fit. Studies of stage-environment fit have been conducted in the context of the transition from middle school to high school (e.g., Barber & Olsen, 2004; Isakson & Jarvis, 1999), not only in the context of the transition from middle school to elementary school. A transition into high school typically involves similar changes as those that occur during a transition from elementary to middle school (e.g., decreased autonomy in the classroom, decreased support from teachers). A transition into high school may be less disruptive than a transition to middle school, since the first transition tends to have more impact (Barber & Olsen, 2004). However, for students who attended a school structured in grades K-8 prior to high school, the transition into high school may be their first move between buildings. Students' transitions into high school have been associated with declines in their academic performance (Barber & Olsen, 2004; Isakson & Jarvis, 1999; Rice, 2001). For high school students, one important developmental challenge of middle adolescence is to become more self-reliant and self-governing (Kimmel & Weiner, 1995; Powell, Ferrar, & Cohen, 1985). In contrast to early adolescents, middle adolescents face increased future-related pressures as they begin to prepare for their lives beyond K–12 education. This perspective draws attention to student-level dimensions, such as achievement and identity (becoming more self-reliant) as well as direction (future-related pressures).

A fit or a mismatch with one's environment may not necessarily be developmental, so we believe that *person-environment fit* (Hunt, 1975) can be a more appropriate term for understanding students' experiences than stage-environment fit. Stage-environment fit addresses the fit between the school setting and a student's developmental needs, but there may be other aspects of the person that can fit or not with the environment. For example, a fit or mismatch may be due to the alignment (or lack thereof) between students' individual epistemological beliefs about the nature of knowing and the approach to mathematics instruction in their classrooms, and these beliefs may not be tied to students' development. Epistemological beliefs have been shown to vary by gender (Gilligan, 1982) and by curricular contexts (Star & Hoffmann, 2005). Boaler (1997) explained high school females' experiences in different mathematics programs in terms of the fit or mismatch between their academic contexts and women's ways of knowing. She drew on the work of Gilligan (1982), who described differences between "separate" and "connected" knowing. Separate thinkers prefer to work with subjects that are characterized by logic, rigor, absolute truth and rationality; and connected thinkers prefer to use intuition, creativity, personal processes and experience. The young women in Boaler's study expressed a preference for learning mathematics through a more open, problem-solving approach that supported their autonomous sense making in mathematics, or an approach more aligned with connected knowing, and they expressed dislike for a more closed, teacher-led approach that was more aligned with separate knowing. Epistemological beliefs represent a student-level dimension (disposition). School-level factors described in this work include teaching practices, enacted curriculum, and expected student activity.

Looking across conceptual lenses that address "fit" (or mismatch) with environment, a common approach is to characterize the degree of overlap between students' perceived needs and preferences and what the environment affords. Both students and school settings change over time. An implicit assumption with this research is that two settings should adjusted to become more aligned (and aligned in ways that also support developing learners). The alternative perspective is that change and challenge is essential to healthy development so the focus should be on how students adjust to those changes and challenges But what frames are available to examine adjustment to changing mathematical contexts for learning? Two perspectives, the concept of a mathematical transition and the lens of boundary crossing, provide alternative ways to view moving into new school settings other than fit with environment.

What counts as a "mathematical transition"? Something to consider in research on educational change is whether changes are noticed by students and how students respond when noticing particular changes. The Mathematical Transitions Project [MTP] team (cf., Smith & Star, 2007; Star, Smith, & Jansen, 2008; Jansen, Herbel-Eisenmann, & Smith, in press, 2012) did assume that changes that adults observed in curriculum and instruction when students moved from one building to another would necessarily be important for students. Our starting point in characterizing what counts as a mathematical transition was to understand the transition experience from students' perspectives (either when moving into a mathematics program that was reform-oriented from a more traditional program or when moving into a mathematics program that was more traditional from a reform-oriented program). The term, "reform-oriented," in this discussion simply signals the possibility of significant changes in curricular content and instructional practice.

We proposed that students experienced a *mathematical transition* if data indicated a significant change along two or more (out of four) dimensions. These dimensions were chosen to capture students' cognitive, affective, and behavioral experiences and included: (a) whether a student reported a significant number of *differences* between their middle school and high school programs, (b) self-reported changes in a student's *disposition* toward mathematics, (c) significant changes in mathematics *achievement*, and (d) self-reported changes in a student's *approach to learning* mathematics. We defined a "transition type" as any combination of significant changes in two or more of these dimensions. (For more on concepts and methods in MTP, see Smith and Star [2007].) Note that factors in school settings were captured from students' perceptions, with respect to the differences that students self-reported. Student-level dimensions that we investigated included their achievement (in terms of course grades over time and overall GPAs), dispositions (self-efficacy, attitude toward mathematics, reports of career goals), and patterns of work (approach to learning). We collected our data over two and a half years at two high school sites and two universities and followed approximately 25 students at each site.

Two of the MTP sites captured students' experiences as they moved from middle school to high school, and results indicated that two-thirds of our focal participants did not experience significant changes in achievement and less than 20% of our high school students changed their learning approaches (Smith & Star, 2007). (When high school students' achievement did change, in approximately three-fourths of these cases, achievement fell.) However, we do not mean to suggest that such lack of change when moving into high school is representative or typical, as we only worked with about 25 students at each high school. Rather, these data suggest that students could have a mathematical transition when moving into high school that does not primarily focus upon changes in achievement or learning approach as the most relevant student-level dimensions.

When students experienced "mathematical transitions" at the two MTP high school sites, they noticed significant differences between their middle school and high school mathematics programs and changed their dispositions toward mathematics. Patterns in students' disposition changes at each site appeared to vary with respect to curricular shifts (Smith & Star, 2007). When the dispositions towards mathematics of students who moved into a high school with a reform-oriented mathematics program (in which the teachers used Core Plus Mathematics Project [CPMP] [Hirsch, Coxford, Fey, & Schoen, 2005]) changed, they became more positive. In contrast to their prior experiences in a more traditional middle school, these high school students reported liking CPMP's focus away from repeated practice on very similar problems, increase in story problems, more group work, and a focus on understanding and sense making. Students who moved into a more traditional high school mathematics program from a reform-oriented middle school mathematics program (in which the teachers used the Connected Mathematics Project [CMP] [Lappan, Fey, Friel, Fitzgerald, & Phillips, 1995]) experienced a range of disposition changes. Among the students whose dispositions changed, there was a mix of both more positive and more negative dispositions toward mathematics in high school, with slightly more students developing slightly more negative dispositions. Students whose dispositions changed reacted to similar factors in school settings (e.g., more distant teacher-student relationships in high school, more challenging mathematics content in high school, more word problems in reform mathematics programs), but some students preferred the middle school and others preferred the high school mathematics program.

Learning during boundary crossing. Rather than assuming that school settings could potentially become more aligned or assuming that change in mathematics programs over time is inherently problematic, the conceptual lens of learning during boundary crossing could be used for understanding how students experience educational change. "Boundary crossing" refers to a person's interactions and transactions across different settings (Akkerman & Bakker, 2011). Jansen, Herbel-Eisenmann, and Smith (in press, 2012) drew upon the concept of boundary crossing to examine two cases of MTP students' transitions into the high school site in which students moved from a middle school that used CMP into a high school with a more traditional mathematics program. Following Akkerman and Bakker (2011), a "boundary" was seen as "a sociocultural difference leading to a discontinuity in action or interaction"

(p. 134). A discontinuity could involve changes along any of the factors in school settings, as presented in Figure 1. Such changes could lead to students' experiences of adjusting their roles in each setting. Following Jackson (2011), "setting" was a distinct physical space, and we considered that different physicals spaces (i.e., school buildings) could typically "enclose" different school practices. Rather than viewing boundary crossing experiences as barriers to learning, they can be perceived as potential resources for learning.

Jansen, Herbel-Eisenmann, and Smith (in press, 2012) presented cases of two students that exemplified two learning processes that could occur during boundary crossing in the process of transitioning out of a reform mathematics program into high school. Drawing on Akkerman and Bakker's (2011) characterizations of learning mechanisms during boundary crossing, our cases illustrated two processes of making sense of practices in multiple contexts: identification and reflection.

> Where identification represents a focus on a renewed sense of practices and a reconstruction of current identity or identities, reflection results in an expanded set of perspectives and thus a new construction of identity that informs future practice. (Akkerman & Bakker, 2011, p. 146)

These conceptualizations highlight that learning during boundary crossing can involve reifying one's current identity (identification) or constructing a new identity through expanding one's perspectives about practices in both settings (reflection). In this work, we present analytic tools for identifying students' boundary crossing experiences and describe the nature of learning that appeared to occur during those experiences.

The case of Bethany (identification) illustrated a student who had a strong preference for her CMP experience in middle school and fought to retain the aspects of that experience that she preferred, even when her high school experience did not provide clear opportunities to do so. For instance, she valued that her middle school mathematics teachers explicitly encouraged her to develop and share her own solution methods, expressed frustration that her high school mathematics teachers were "teaching one way… I've never done the same way as the teacher," and experienced conflicts with her mathematics teachers when they took off points for solutions that were correct yet did not align with their taught procedure or when they would not listen to her ideas for how to solve the problem. Through making sense of her boundary-crossing experience, she appeared to solidify her identity as a learner and doer of mathematics.

Ethan's case (reflection) demonstrated a student who, through his continual use of metaphors, expanded his perspective about school mathematics through experiencing two different mathematics programs. One of these metaphors included running water over an ice cube tray. He observed that the middle school mathematics teachers filled the ice cube trays slowly and carefully while the high school mathematics teachers ran the water quickly over the trays, which represented the degree to which teachers monitored student understanding in each setting. He reported liking his high school mathematics program slightly more than his middle school mathematics program, because he appreciated what he perceived to be an increase in autonomy and challenge. Learning occurred for Ethan through reflection because he constructed new understandings of the differences between the two settings and developed a new sense of identity (that he called "ambidextrous") such that he believed that he could be successful in either type of setting.

High School to Post-Secondary School (College and/or Careers)

We recognize that ideally all students should have a diversity of learning and work options beyond high school; not every student should be expected to attend a four-year university. This diversity of potential post-secondary experiences adds additional challenges to studying the transition out of high school. Even college-bound students who have been historically successful in mathematics may not be successful in college mathematics (Smith & Star, 2007). It is important to understand the range of factors at play in students' experience with the transition to post-secondary experiences. Hull and Seeley (2010) note some factors in students' experiences that appear to be lacking: adults might have lower expectations for students' post-secondary goals than students have for themselves and students are often lacking information about post-secondary experiences, including what colleges require for entrance or placement in particular mathematics courses.

Although we acknowledge the range of post-secondary experiences, the prior research that we describe below primarily focuses upon students' transition from high school to college mathematics programs. We describe two conceptual lenses, including the MTP conception of a mathematical transition and the concept of "rite of passage." Additionally, we describe other transition issues that students might experience when moving into college or a work career.

What counts as a "mathematical transition"? There were two university sites in the MTP project; one included students who experienced CPMP or another reform-oriented curriculum in high school and entered a university with a more traditional calculus program and the other site included students who experienced a more traditional high school mathematics program and moved into a university with a reform-oriented calculus program.

At both university sites, the changes that students experienced appeared to be more similar than different, which suggests that their transitions had more to do with moving into college than shifts in their curriculum materials (Smith & Star, 2007). More than four-fifths of the students at both university sites experienced drops in their achievement. When students' dispositions toward mathematics changed at either university site, their dispositions became more negative. About half of the students at each university site changed their approaches to learning mathematics. Students who moved into the university that had a more traditional mathematics program than they had experienced in high school changed their intellectual participation by struggling to attend class when the dominant activity was lecture presentation in college. Students may have struggled to attend class due to being able to choose whether or not to attend class in college or because they had a preference for their high school mathematics courses that were not lecture-oriented. However, at both sites, the general pattern in their learning approach changes was to read mathematics textbooks more carefully and extensively in college, to complete more homework (even when voluntary), study more for tests, and to seek more help from institutional resources or peers (but not from teachers) in college. Most participating students at both sites reported significant differences between high school and college. Some of these differences were more about the move into college generally, such as the new and more difficult mathematics content that they observed, and other differences were more closely aligned with the shift in curricular programs, such as the increase or decrease in contextual story problems, the increase or decrease of fixed procedures available to solve the problems, and the increase or decrease of the expectations to explain solutions in writing or verbally. Although most students at both universities experienced change on our dimensions, these changes seemed to be more about moving into college generally than the shifts in curricular programs.

Rite of passage. Clark and Lovric (2008, 2009) addressed a need for a theoretical model to understand the high school to university transition in mathematics by adapting the concept of "rite of passage." This concept affords an understanding of both the nature of the transition experience and suggests possibilities for supporting students as they move into college. Below, we will describe how the rite of passage concept provides insights on the nature of the transition experience, and later in the paper we will revisit the concept to consider how to support students' transitions into college.

Rite of passage is a concept from anthropology that describes how people experience a crisis, according to Clark and Lovric (2008, 2009). In such a crisis, routines are interrupted, changed, and distorted (discontinuities in experience). In rites of passage, young people re-establish balance and bring back more regular routines. There are three phases associated with a rite of passage: separation (distancing one's self from a high school mathematics experience and beginning to anticipate the tertiary experience), liminal or transitional phase, and the incorporation phase. The process involves cognitive conflict and culture shock. This rite of passage is marked by a physical separation from family and former homes; combined with the large scale of university settings and programs, shock and stress may be inevitable. The success of moving through a rite of passage depends at least in part upon the assistance offered to the individual undergoing the experience.

Clark and Lovric (2008, 2009) relate the experience of moving from secondary mathematics programs into tertiary programs. They describe the discontinuities in terms of college faculty perceiving a lack of preparation in students' technical or procedural facility and analytic skills and deficiencies in students' fundamental notions about the nature of mathematics (particularly a lack of understanding about the role of proof in mathematics). Additionally, citing Tall (1991), they note that college students struggle with building the cognitive apparatus needed to handle advanced mathematics. A student who completes this rite of passage becomes able to think in more productive ways that are aligned with the new environment. From the perspective of rite of passage, the transition into college will likely involve significant discontinuities. Rather than trying to remove the discontinuities, the goal is to think about how to support students with successfully navigating the discontinuities. (Clark and Lovric's [2008, 2009] suggestions, as informed by the rite of passage concept, will be explored later in this paper.)

System-Level Responses to Support Students as They Progress Through School Experiences

Given the range of discontinuities students might experience in school-related factors as they move through grade bands over time (and associated or co-occurring responses at student-level dimensions), it would be useful to explore some recommendations for supporting students with their transitions through mathematics programs over time. We do so with a caveat: many of these system-level responses have not been thoroughly examined empirically. Some of the recommendations address minimizing the discontinuities between factors in school settings at the transitions between grade bands. Other recommendations take discontinuities between grade bands as a given and focus on how to help students navigate them. More research is needed to understand the conditions under which these system level responses are more and less effective for supporting students in their transitions across grade bands.

Regarding efforts to minimize discontinuities, a consistent recommendation has been for teachers to communicate across grade bands about mathematics teaching and learning (Brown & Seeley, 2010; Hull & Seeley, 2010; Schielack & Seeley, 2010). Teachers at the earlier temporal stages of transitions can develop awareness of what their students will experience in the future and prepare them. Teachers at the later temporal stages can learn more about what their future students will have experienced and what they might be capable of doing or understanding about mathematics. The specific recommendations about how to go about this sort of communication vary slightly. It has been suggested that elementary and middle school mathematics teachers can visit each other's classrooms and have comparative discussions about assignments and students' work (Schielack & Seeley, 2010). Middle school and high school teachers could engage in cross-site collaboration to improve alignment in instructional practices and collaboratively study mathematical goals and expectations (Brown & Seeley, 2010). College faculty and high school teachers could collaborate to develop a shared understanding about what students need to know, develop tasks that exemplify these expectations, and establish exemplars of student work that reflect the depth of knowledge that should be promoted (Hull & Seeley, 2010). To engage in such cross-site collaboration, teachers would need support (in terms of time, structure, and guidance) and shared motivation for working toward better alignment across grade bands. Where the latter may exist in some, perhaps many communities, the support resources typically do not.

Given potential challenges associated with reducing unproductive discontinuities, system-level supports designed to support students with navigating transitions seem more pragmatic and promising. Teachers could create a support network with other teachers, counselors, administrators, and parents to provide students with an early vision about what being "good in mathematics" could mean for students' futures (Schielack & Seeley, 2010). Middle school teachers could work to create classroom cultures that actively engage students such that they support students' cognitive, emotional, and social development (Brown & Seeley, 2010). These efforts could usefully promote the ideas that mathematical competence is malleable rather than fixed and that being good at mathematics involves effort rather than solving problems quickly, and provide every student with a sense of belonging in the mathematics classroom. High school teachers could promote high expectations for every student, build strong relationships with students to reinforce high expectations, and know about (and communicate with students about) what students need to do to prepare for college mathematics courses and mathematics placement exams (Hull & Seeley, 2010).

To prepare for success in tertiary education, high school students should receive clear messages about the importance of taking mathematics for all four years in high school and how effort matters for mathematics learning, support for learning to read mathematics textbooks for understanding, and encouragement to form study groups among peers.

Seeley and colleagues have made some specific content recommendations to support students with navigating transitions. For the middle grade bands, they advocate promoting proportional reasoning to support success in high school mathematics (Brown & Seeley, 2010). In high school, they advocate increasing mathematical expectations for students, but rather than advocating that every student take calculus, they recommend that some students take a fourth year mathematics course consisting of statistics, probability, data analysis, and modeling (Hull & Seeley, 2010). These "new" areas of mathematical content are promising focal areas given the nature and demand of many fields of work, before and after college.

Rite of passage and implications for supporting the college transition. Considering the rite of passage conceptual lens, Clark and Lovric (2008, 2009) made some specific recommendations to assist students as they navigate their transition into their college mathematics programs. Rather than change college mathematics courses to be more like high school courses, the rite of passage perspective suggests that it is more appropriate to focus upon making expectations more transparent to students. This would mean telling high school students more directly, accurately, and in detail about their future work in university or college mathematics classrooms.

Regarding mathematics placement tests, Clark and Lovric (2009) suggest that recognizing that a rite of passage involves the whole student, an effective mathematics placement test would incorporate more than mathematics content. Beyond testing mathematics background knowledge and skills, placement tests could capture the whole individual. This would include measuring students' attitudes toward learning mathematics, their motivation, and their preferences for learning and social engagement in the classrooms, and designing appropriate mathematical learning experiences according to the outcomes.

These authors note that a rite of passage takes time and should not (and cannot) be accelerated.

> Rather than trying to "ease the transition" or "make it smoother," it [a successful transition program] needs to acknowledge that the transition [to college] will be painful, difficult, and—perhaps most importantly—that it will take time. Students undergoing transition need to know that all discomfort, pain, stress, even severe anxiety—in the end—will be proven worthwhile. Confusion and uncertainty are integral parts of everyone's learning process (Clark & Lovric, 2009, p. 764).

Realistic expectations for the length of time it will take for students is important, as short orientation sessions about how to be a more effective note-taker or how to manage time are not enough to help students (Clark & Lovric, 2008). We should not expect that short, one-shot workshops are enough to support students with a transition to college.

Additionally, a rite of passage suggests that individuals who engage in the process should take some responsibility for it (Clark & Lovric, 2008). To ease the process of students taking responsibility, groups of students can be brought together to support each other as they navigate the transitions together (Clark & Lovric, 2009). Students who have already successfully transitioned into college can serve as mentors to first-year students. It is not inappropriate, from this perspective, to expect first-year college students to accept at least some responsibility for taking initiative to negotiate the transition. Too much help may serve to disempower students.

Promising Possibilities for Future Research

Given the complexity of students' experiences in school over time, we are hesitant to prescribe specific questions for future research. However, we would like to suggest an issue to consider and a promising theme for researchers to pursue if they are interested in better understanding students' transitions in school mathematics. An issue to consider is which processes and outcomes to investigate when conducting research on students' transitions. Additionally, we believe that a promising path to pursue would be to further document the effects of interventions designed to support students with their school mathematics transitions over time.

We recommend that researchers build upon and extend this line of research through examining factors other than achievement and course-taking. Outcomes such as achievement and performance measures have dominated prior research (cf., Barber & Olsen, 2004; Hill & Parker, 2006; Isakson & Jarvis, 1999; Post, Medhanie, Harwell, Norman, Dupuis, Muchlinski, Andersen, & Monson, 2010; Rice, 2001). However, dispositional factors may be as potent for mathematics learning as any set of factors, particularly as a mediating variable between instruction and performance or understanding. Accounting for these mediating variables could enhance research on transitions by providing explanations or insights about why students' performance or achievement outcomes or course-taking patterns occur.

Future studies about transitions between school settings should be more closely situated in relation to shifts in curriculum or instructional practices of specific subject matter. Relating studies of transition in relation to specific subject matter can provide insights for how the teaching of particular content can support or constrain the degree to which students will continue to engage or not with that content.

There is a need to continue to report the effects of promising interventions that support productive outcomes. Certainly this paper did not exhaustively explore all of the research that has been conducted on productive interventions, but there is a need for more research that uncovers conditions that lead to students experiencing school mathematics transitions in productive ways. We recognize the challenge in this sort of work. There is a severe difficulty of relating change in any variable to the effect of one factor represented in the intervention.

Conclusions

In this paper, we examined questions about aspects and dimensions of students' transitioning through educational settings over time along with concerns for system-level responses to support students as they move through these transitions. We highlighted conceptual lenses to help understand students' experiences over time during transition points in school mathematics programs as well as issues that students may experience due to factors in school settings and student-level dimensions. We advocate for attention, through both research and practice, to students' socio-emotional well-being and developing identities as they navigate changes in their mathematics programs over time. Understanding the nature of changes that students experience at transition points across their school experiences can be helpful for those who are invested in supporting students' mathematics learning and development.

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