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Second-Career Mathematics Teachers' Knowledge of Mathematical Connections

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Abstract

This study investigated the ways in which second-career mathematics teachers exhibit and discuss their knowledge of mathematical connections. Results indicated that the second-career teachers were most likely to exhibit knowledge of mathematical connections when creating a mathematics problem from a given topic and when making a mathematical connection to a context outside of mathematics. The data analysis indicated that those second-career teachers that exhibited knowledge of mathematical connections were hesitant to use this knowledge in their teaching for reasons including their own perception of students' ability. The implications of these findings inform future preparation and recruitment of second-career mathematics teachers.

Keywords: Teacher education; Mathematics education

For quite some time, second-career teachers have been recruited into the education system due to shortages of teachers in particular geographic areas (e.g., urban schools) and within particular content areas (e.g., science and mathematics; Cornett, 1986; McCree, 1993; Stoddart & Floden, 1995). Now, "between 33 percent and 48 percent of those entering teaching today come from another line of work rather than straight from college (Johnson & The Project on the Next Generation of Teachers, 2004)" (Johnson & Kardos, 2005, p. 11). The United States is presently undergoing an economic crisis; industries that were once abundantly profitable are now near extinction. The resulting reduction in workforce is evident in both white-collar and blue-collar positions. At the same time, there has been an increase in the number of preparation programs designed to recruit and train second-career teachers (Haselkorn & Hammerness, 2008), and the federal government has joined in this effort by funding programs such as $E = MC^2$ and other Transition to Teaching grant programs. The result is a perfect storm of mid-career professionals with technical experience, lacking real-world industrial employment opportunities, with streamlined routes to teacher certification.

One argument made in support of the movement of second-career professionals into teaching is that, since they have degrees in the subjects in which they teach (e.g., engineering degree to teach mathematics or biology degree to teach science), they have the requisite content knowledge. Other arguments suggest that second-career teachers, as a product of their experiences from their initial career, may bring a knowledge of technology to teaching that can be applied to classroom learning (Marinell, 2008; Mayotte, 2003), an ability to engage in real-world mathematical problems that are often ill-defined (Chambers, 2002; Gainsburg, 2007; Marinell, 2008; Mayotte, 2003), and a knowledge of connections between different mathematical areas (e.g., algebra and geometry) with contexts outside of mathematics (e.g., connections between math and science; Chambers, 2002; Marinell, 2008).

The assumption being made from these latter arguments is that adults who interact in their initial career with specific content develop particular knowledge and skills with respect to that content, which they can then draw upon in effective ways as teachers. Whether second-career teachers develop particular knowledge with respect to specific content and whether and how they might draw upon that knowledge in the context of teaching remains under-examined in the field. Building a knowledge base that can begin to address this void is not limited to any single content area, but growth in understanding may be best achieved through studies that are content specific. This study specifically addressed the following research questions:

1. In what ways do second-career mathematics teachers exhibit knowledge of mathematical connections?
2. For those second-career mathematics teachers who exhibit evidence of knowledge of mathematical connections, in what ways do they speak about the sources of their knowledge?
3. For those second-career mathematics teachers who exhibit evidence of knowledge of mathematical connections, in what ways do they speak about the use of their knowledge in their instruction?

Methods

Participants for this study were purposely chosen based on their teaching, academic, and professional experiences. Procedures to select participants and method of data collection were approved by the appropriate university institutional review board. In order to participate in the study, subjects had to be currently teaching or have recently taught mathematics in any grade from 7 to 12. Participants were also chosen based on the degree to which their academic and initial career experiences involved mathematics. By choosing second-career mathematics teachers with academic and professional experiences with mathematics, there was an increased opportunity to see knowledge of mathematical connections in the responses to the tasks and to see potential relationships between participants' initial career experiences and this knowledge. The goal was to find the participants that seemed most likely to have knowledge of mathematical connections.

To determine the extent to which participants' prior academic and career experiences were *mathematically oriented*, I developed definitions to guide my interpretation. For participants' undergraduate degrees, a *mathematically-oriented degree* was defined as requiring at least two courses in calculus and one other mathematics content course at the 300 level or above. The guidelines for a *mathematically-oriented initial career* focused on how often (e.g., daily, monthly) participants reported using mathematics, how they stated that mathematics was used in the context of their career, and what level of mathematical knowledge (e.g., high school, college, graduate level) was required of them. These guidelines were transformed into questions that were given to potential participants in the recruitment form.

Phase One Data Collection

Selection of participants for phase one data collection. Before the recruitment form could be sent to second-career mathematics teachers, potential participants needed to be identified.

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Identification of participants began by contacting teacher preparation programs that specialize in preparing second-career mathematics teachers (e.g., programs similar to Transition to Teaching and Troops to Teachers), and by contacting current and former mathematics specialists who were in contact with a large number of mathematics teachers in the area. Potential participants were sent a recruitment form that collected data on participants' educational and employment experiences, generated from the guidelines previously discussed. The recruitment form asked participants to identify their undergraduate degree and to note whether they would describe it as mathematically oriented (that is, requiring courses such as calculus and differential equations). The participants were also asked to provide examples of how they used mathematics in their previous careers to ascertain the level of mathematical knowledge required for their job (e.g., high school or college level equivalent) and to identify how often they used mathematics in those jobs. Participants who held an undergraduate degree in a mathematically-oriented field, had at least four years of work experience in a mathematically-oriented profession, and used mathematics on a regular basis (e.g., at least weekly) in their initial career were asked to participate.

Table 1
Participants Educational, Initial-Career, and Teaching Experience

Participant	Gender	Degree	Initial Career	Years in Initial Career	Years Teaching
Eric	Male	BA Mathematics	Engineer	4	2
Jane	Female	BS Economics	Computer Programmer Analyst	15	9
Lori	Female	BS Mathematics	Information Specialist	23	1
Meghan	Female	BS Civil Engineering	Engineer	4	9
Mike	Male	BA Mathematics	Actuary	11	4
Reba	Female	BS Computer Science	Computer Programmer	18	5
Rick	Male	BS Engineering	Engineer	14	9
Ronald	Male	BS Engineering	Military & Telecom-munications	33	3
Sam	Male	BS Computer Science	Web Development	15	6
Tara	Female	BS Engineering / Mathematics	Aerospace Engineer	10	4
Ted	Male	BS Chemistry	Chemist	20	5
Terry	Female	BS Biology	Chemist	7	4

Out of the 26 qualified participants sent the questionnaire, 12 returned the completed questionnaire and were paid $10 for their time. The 12 participants for this study were all second-career high school mathematics teachers (one of the participants was teaching physics for the current semester and one had just begun a Ph.D. program) with at least four years of full-time initial career experience in a mathematically-oriented field. Participants' initial fields of employment included engineering (n = 4), actuarial science (n = 1), chemistry (n = 2), and computer programming

($n = 5$). The participants all held undergraduate degrees in mathematically-oriented fields, including mathematics ($n = 4$), engineering ($n = 4$), computer science ($n = 1$), chemistry/biology ($n = 2$), and economics ($n = 1$). To assure that these degrees fit the guideline for mathematically oriented, course taking requirements for each major were checked at a local university. All of the degrees met or exceeded the guideline requirement. Table 1 displays information about participants' undergraduate degrees, initial career experience, and teaching experience.[1]

Phase one data collection: Questionnaire. The first phase of data collection consisted of a questionnaire with two sections: (a) tasks to elicit second-career teachers' knowledge of mathematical connections situated in the context of evaluating and creating mathematical problems and (b) an open response section asking participants to provide examples of how they draw on their knowledge of mathematical connections to inform their teaching.

The eight tasks that represent the first section of the questionnaire are divided into four subsections. These subsections represent the two types of knowledge of mathematical connections being examined in this study and two situational opportunities (see Table 2). The two situational opportunities that addressed participants' ability to exhibit knowledge of mathematical connections among mathematical ideas were (a) the examination of and (b) the creation of mathematical problems. The *Principles and Standards for School Mathematics* (National Council of Teachers of Mathematics [NCTM], 2000) argues that teachers can help students seek and make use of knowledge of mathematical connections through problem selection. "Problem selection [by teachers] is especially important because students are unlikely to learn to make mathematical connections unless they are working on problems or situations that have the potential for suggesting such linkages" (p. 359). It follows that teachers themselves need to hold knowledge of mathematical connections to inform their problem selection.

The first situational opportunity asked the participants to examine potential mathematical connections in provided mathematics problems; the second situational opportunity asked the participants to create a mathematics problem. In Table 2, the rows list the types of mathematical connections and the columns list the situations in which those mathematical connections may be drawn upon.

Table 2
Problem Types: Mathematical Connections Across Situational Opportunities

Situational opportunity	**Examining mathematical problems**	**Creating mathematical problems**
Demonstrate knowledge of connections among mathematical ideas.	Two tasks	Two tasks
Demonstrate knowledge of connections of mathematics with contexts outside of mathematics.	Two tasks	Two tasks

Connections among mathematical ideas. One type of knowledge of mathematical connection that these questionnaire tasks examined was participants' ability to make connections

1 Pseudonyms are used for participants throughout the text to protect their anonymity.

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among mathematical ideas. In an effort to create tasks that could best elicit participants' knowledge of connections among mathematical ideas, special attention was paid to whether the mathematics problems themselves would elicit knowledge of mathematical connections. Mathematics problems are constructed and used for several purposes, including for practice with and assessment of specific procedural skills. For example, the following problem can be found in many traditional algebra textbooks—Evaluate: -(8 + 5). This problem provides procedural practice, but the lack of context within the problem may make it more difficult to identify and connect relevant mathematical ideas. However, there are mathematics problems purposely constructed to access knowledge beyond a procedural level; subgroups of these problems are designed specifically to support the use of knowledge of mathematical connections. The following problem is from *High School Mathematics at Work* (Mathematical Sciences Education Board [MSEB] & National Research Council [NRC], 1998), whose authors constructed problems for this text based on tasks solicited from leaders of high school curriculum and assessment projects, mathematicians, and policy leaders.

> A lottery winner died after five of the twenty years in which he was to receive annual payments on a $5 million winning. At the time of his death, he had just received the fifth payment of $250,000. Because the man did not have a will, the judge ordered the remaining lottery proceeds to be auctioned and set the minimum bid at $1.3 million. Why was the minimum bid set so low? How much would you be willing to bid for the lottery proceeds? (p. 111)

The content of the lottery scenario has the potential to elicit or support knowledge of several mathematical connections—a necessary component of a task intended to examine participants' knowledge of connections among mathematical ideas. The structure of the problem provides the framework for students to potentially engage "in the exploration of interest rates, exponential growth, and formulating financial questions in mathematical terms" (MSEB & NRC, 1998, p. 111).

To provide the participants opportunities in which the mathematical problem itself supports identification of mathematical connections, the tasks chosen for the questionnaire most closely resemble the lottery problem discussed above. That is, problems that (a) are not straightforward exercises such as 5 + 3, (b) that include a context (e.g., word problems), and (c) that contain mathematics generally considered to be at a high school level of difficulty. To do this, I used problems with provided solutions from texts (e.g., NCTM, 2000; MSEB & NRC, 1998) that highlight the possible mathematical connections that could be made among mathematical ideas.

In creating tasks to elicit participants' knowledge of connections among mathematical ideas, one must also consider the role of participants' mathematical content knowledge. That is, participants may be more likely to exhibit their knowledge of mathematical connections about topics they are familiar with, as opposed to mathematical topics that are unfamiliar or obscure. For example, a topic such as the Maclaurin series (from intermediate analysis) may not be as well known to the participants as linear equations, area, volume, or integration (topics generally covered in high school curriculum). To address this issue, I have provided three high school level mathematics problems within Tasks 1 and 2 such that each problem represents a different mathematical content area. For example, in Task 1, the three mathematical areas represented in order of the problem presented are probability, geometry (midpoint-of-hypotenuse theorem), and algebra (exponential functions).

For Tasks 3 and 4, there is also a choice between three mathematical content areas. For example, I have used mathematical topics that generally reflect a chapter in a high school textbook (e.g., exponents) as opposed to more specific content that might be covered within that chapter (e.g., logarithms). Drawing upon high school level mathematical topics is appropriate because all of the participants are high school mathematics teachers and as such should be familiar with at least one of the content areas provided. Table 3 shows the mathematical topics for the four tasks focused on eliciting participants' knowledge of mathematical connections among mathematical ideas.

Table 3
Mathematical Topics per Task

Task	Topic choice one	Topic choice two	Topic choice three
Task 3	Writing linear equations	Quadratic equations	Exponents
Task 4	Area	Distance formula	Loci
Task 7	Writing linear equations	Quadratic equations	Powers & exponents
Task 8	Similarity	Central tendency	Trigonometric identities

Connections to contexts outside of mathematics. A second mathematical connection these questionnaires examined was participants' knowledge of mathematical connections to contexts outside of mathematics. As before, these tasks were created within two situational opportunities: participants were asked to examine mathematical problems for potential linkages to contexts outside of mathematics and were asked to create problems that contain such linkages. Again, attention was paid to the role of participants' content knowledge in the design of these tasks. For each task, the participants were given three mathematics problems reflecting three distinct content domains (Tasks 5 and 6) or were given three high school level mathematical content areas to choose from for the creation of each of their mathematics problems (Tasks 7 and 8). Grounding the tasks in high school level mathematics content increased the likelihood that the participants, all of whom are high school mathematics teachers, would be familiar with at least one of the options.

Selection of the mathematics problems intended to elicit participants' knowledge of mathematical connections to contexts outside of mathematics was again guided by the National Council of Teachers of Mathematics's (NCTM, 2000) discussion of mathematical connections. The *Principles and Standards for School Mathematics* (2000) identified two overarching contexts outside of mathematics where connections may be made: connections with another academic discipline and connections to real-world situations. The first requires making a connection with another academic discipline or subject area (e.g., science, history). For example, in Task 5, the falling object problem, one could relate the mathematical concept of writing algebraic expressions to the concept of gravity in physics.

The second context outside of mathematics where mathematical connections may be made requires making a connection with real-world situations. *Real-world situation* is a broad descriptor of mathematical problems, and there may be disagreement over what real-world problems are or need to be. For the purposes of this study, I have chosen to narrow the definition of real-world problems by developing two categories: well-defined real-world problems and ill-defined

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real-world problems. Narrowing the definition in this way potentially aligns with the types of mathematical problems experienced in the high school classroom (well-defined) and the types of mathematical problems likely experienced in the participants' initial career experiences (ill-defined).

According to Jonassen (1997), well-defined problems are "constrained problems with convergent solutions that engage the application of a limited number of rules and principles within well-defined parameters" (p. 65). For example, the Fahrenheit and Celsius scales are related by the formula F = 9/5 (C) + 32. If a child has a temperature of 100 degrees Fahrenheit, what would his temperature be in Celsius? This problem contains all the necessary elements needed to arrive at a solution, there is only one solution, and the solution process is evident in the problem by the given formula. Thus, this is considered to be a well-defined problem.

In contrast, ill-defined problems "possess multiple solutions, solution paths, fewer parameters which are less manipulable, and contain uncertainty about which concepts, rules, and principles are necessary for the solution" (Jonassen, 1997, p. 65). For example,

> In medicine, calculation of body surface area is sometimes very important. For example, severe burns are usually described as covering a percentage of the body surface area. Some chemotherapy drug dosages are based on surface area. How might body surface area be measured? What factors influence the accuracy of the estimates? (MSEB & NRC, 1998, p. 145)

The above problem provides no explicit means for solving the problem (e.g., a formula is not provided), there may be multiple answers considered correct depending on the approach used, and elements of the problem needed to find a solution are not specifically defined (e.g., relationship between a person's height and weight).

Although well-structured and ill-structured real-world problems differ in their structure, they are not separate entities. Instead, well-defined and ill-defined problems reside on a continuum that "is a function of the complexity of the problem, clarity of the goal state and the criteria addressing it, the prescriptiveness of the component domain skills, and the number of possible solutions" (Jonassen, 1997, p. 87). Participants' ability to exhibit knowledge of mathematical connections to contexts outside of mathematics may be more likely if participants were provided opportunities from more than one point on this continuum. To address this issue, Tasks 5 and 6 include both ill-defined and well-defined real-world mathematics problems.

Connection to teaching. The second section of the questionnaire provided an opportunity for the subjects to share examples of how they have used knowledge of mathematical connections among mathematical ideas and to contexts outside of mathematics in their mathematics instruction. In contrast to Tasks 1–8, the open-ended section provided fewer constraints in terms of the content and situational opportunity within which the participant was allowed to exhibit her or his knowledge. Specifically, the open-ended section of the questionnaire asked participants to respond to the following prompts:

- Provide one example of how you have used your knowledge, with respect to your ability to recognize connections among mathematical ideas, in your mathematics instruction related to evaluating mathematical problems or creating mathematical problems.

- Provide one example of how you have used your knowledge, with respect to your ability to recognize mathematics in contexts outside of mathematics, in your mathematics instruction.

This last section of the questionnaire attempted to cast a large net in hopes of gathering remaining data on how and when second-career mathematics teachers exhibit and use knowledge of mathematical connections. This data is relevant to research question one (ways in which knowledge is exhibited) and research question three (use of knowledge of mathematical connections in instruction).

Data analysis of phase one. As a means of organizing the analysis of the questionnaire, a table was created with the names of participants on the vertical axis, descriptions of tasks (including open-ended responses) on the horizontal axis, and related assigned codes. Miles and Huberman (1994) suggest that such organization may assist in drawing conclusion. Each code was assigned a specific color in the table as a way of assisting the observation of frequencies. The table was used to examine patterns (a) between Tasks 1–4 and the first open-ended response (both related to connections among mathematical ideas), (b) between Tasks 5–8 and the second open-ended response (both related to connections to contexts outside of mathematics), (c) across all participants' responses related to each type of knowledge of mathematical connections, and (d) between participants' responses across the two types of situational opportunities. The analysis of phase one data collection informed the way in which data for phase two was collected.

Phase Two Data Collection

Selection of participants for phase two data collection. One of the products of the collection and analysis of the first phase of data collection was evidence of knowledge of mathematical connections. With a sample of only 12 participants, it would be difficult to make conclusions about all second-career mathematics teachers; however, within the data collected, it is possible to discuss patterns in the way the participants exhibited evidence of knowledge of mathematical connections. This was useful in choosing candidates to participate in the second phase of data collection because the second phase was focused on the sources and use of this knowledge.

While reviewing results of the analysis of the first phase of data collection, several interesting patterns emerged. For example, some participants exhibited knowledge of one type of connection, but the data showed a lack of evidence of knowledge of the other. This occurred in both directions related to the two connections: One participant exhibited knowledge of connections among mathematical ideas but did not exhibit knowledge of connections to contexts outside of mathematics; however, another participant showed evidence of the exact opposite situation. To determine which patterns were relevant with respect to the study's research questions and for the selection of participants, I returned to the research questions to support alignment between the data to be collected and eventual conclusions to be drawn.

Although research questions two and three relate to two different aspects of second-career mathematics teachers' knowledge of mathematical connections, attainment versus use, both questions have an underlying assumption that the participants hold knowledge in this area, at least when related to the evidence of knowledge of other participants in the sample. That is, it would be difficult to describe in what ways second-career mathematics teachers discuss the use of their knowledge of mathematical connections if the evidence does not suggest they have this

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knowledge. Given the constraint provided by the research questions, I narrowed the choice of participants for the second phase of data collection to the four second-career mathematics teachers who most often exhibited knowledge of mathematical connections.

To some extent, the narrowing of the participants was relatively straightforward. For example, one of the participants, Ellen, had no responses coded as representing knowledge of mathematical connections, but in comparison Rick had 7 out of 10 responses that were coded as exhibiting knowledge of mathematical connections. I narrowed the selection of participants to those that had at least two responses coded as exhibiting knowledge of the two types of mathematical connections and that also had at least six responses of these responses in total. Five participants met this threshold: Rick, Meghan, Ronald, Tara, and Mike.

Before randomly selecting the four second-career mathematics teachers to participate in the interview, I reviewed my notes from data analysis of the questionnaire relating to these five participants. I specifically looked for data that would inform either the source of knowledge of mathematical connections (RQ2) or the use of knowledge of mathematical connections (RQ3). One response initially emerged from this review: Ronald's responses within the questionnaire explicitly discussed the way in which teaching in an urban environment influenced his use of mathematical connections in his teaching.

> I'll be very honest here. I teach in an inner city high school where there is a significant gap in basic math skills among most of my students. I spend a lot of my time reinforcing basic skills like adding and subtracting positive and negative numbers, working with fractions etc., in the context of basic instruction in Algebra 1 and 2 topics. I sometimes use examples from my previous two careers (military and the telecom business) to give students examples of how some of the concepts they are learning are used. For example, when graphing linear functions, I showed them an example of how a Cartesian plane resembles a military map grid. I also used very simplified examples of how we used linear optimization to develop pricing curves when I worked for a telecom company. But, with the exception of very few students, these examples were well beyond where my students are with their math skills. I want to be careful that I don't give the impression that I believe my students are not capable of making connections. Not so. I just have a lot of work to do before I can get them there.

Ronald's response explicitly discusses the impact of the teaching environment on his use of mathematical connections in teaching.

My next step was to go through the responses for each of the five second-career teachers that met the criteria for the interview portion of the study (Rick, Ronald, Meghan, Tara, and Mike). One other second-career teacher, Mike, also made reference to teaching in an urban environment. Mike's response focused more on the nature of the mathematical problems provided in the questionnaire. In response to the choice of mathematical problems in Task 6, Mike stated, "I wasn't crazy about the contextual potential for urban high school students in any of the questions." Mike provided a less-detailed response than Ronald related to teaching in an urban environment, but it still suggests that teaching in an urban environment impacts his use of knowledge of mathematical connections. Further analysis of the responses looking for other references to the role of teaching in urban teaching environment and evidence (exhibited) of knowledge of mathematical connections was conducted, and I found that Mike was the only other participant that also fit this type.

Why this pattern is relevant to this study emerges from research question three. As mentioned previously, one of the goals of the study is to develop a better understanding of the ways in which second-career mathematics teachers perceive their use of knowledge of mathematical connections in instruction. Mike and Ronald's discussion of the influence of urban teaching suggested that, to some extent, they were conscious of at least one factor influencing the use of their knowledge of mathematical connections.

I re-examine the responses for the remaining eligible second-career teachers (Rick, Meghan, and Tara) for data that may suggest other factors influencing their use of mathematical connections. As no other patterns emerged, I randomly chose two of the remaining three participants by assigning each a number and using a random number generator. Rick and Meghan were selected and were asked to participate in the interview process.

Second phase of data collection: Interview. The interview protocol for the second phase of data collection was divided into three sections. The first section of the protocol gathered information related to the background of the participant including the number of years they have been teaching mathematics, mathematics involved in their initial career experience, and how they perceive the relationship of those experiences to teaching. This section helped to provide a rich description of the background of the second-career teachers and to suggest relationships between their knowledge of mathematics in general and their prior experiences that were useful in refining upcoming interview questions. The second section of the protocol focused on building on the data collected from the questionnaire, specifically asking the participants how they interpreted the two types of mathematical connections included in the study, how they viewed their own knowledge of these connections, and how they account for having this knowledge (RQ2). The third section of the protocol focused on how the participants perceived their use of knowledge of mathematical connections in their teaching, particularly what variables inhibited or supported the application of this knowledge (RQ3).

Data analysis of phase two. All interviews were conducted by telephone, recorded, and later transcribed. The analysis of the interviews began by reviewing notes made during the interviews and by reading each of the transcripts. I then began to group the participant responses into three categories. This analysis was consistent with the comparative approach and as such, upon the initial open-coding, resulted in broad categories (Glaser & Strauss, 1967). The three categories loosely aligned with the three research questions for this study. The first category (RQ1) included responses related to mathematical knowledge; initially this included any mathematical knowledge including the two types of connections discussed in this study. This category captured a range of responses, from responses describing knowledge of specific mathematics content to responses in which participants described their perceived lack of expertise of mathematical knowledge. For example, Mike's suggestion that he felt he had a particularly strong understanding of probability and statistics and multi-variable calculus, and Rick's statement, "I wouldn't say that my math |expertise increased during either one of those careers," were initially categorized in this way.

The second category (RQ2) included responses related to teaching; this included references to the use of mathematics in teaching as well as any reference to school related issues or reference to one's students. This category was also purposely broad, designed to capture any data related to teaching. Responses in this category ranged from participants' descriptions of the number of years they have been teaching and under what conditions to the potential influence of teaching on their use of knowledge of mathematical connections. For example, Meghan's discussion of just

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finishing her tenth year of teaching fit this category as well the way she described how her view of using mathematical connections in teaching has changed:

> I liked that idea, but the change that I have had in my perspective on that is that we need to teach basic concepts as well and if you try to do the relational problems too early then it becomes very confusing for kids.

The third category (RQ3) included responses related to participants' initial career or other prior experiences; this included references to prior academic and personal experiences. Again, this category was kept purposely broad and was designed to capture any data related to participants' prior experiences that were not explicitly related to teaching. Responses that fell into this category included identification of and time spent in an initial career and descriptions of personal hobbies that participants discussed as relevant to their knowledge of mathematical connections. Examples of responses included in the third category included Mike describing his background, saying, "I was an actuary for about twelve years and then got into teaching after that," and Ronald's description of using mathematics in home improvement:

> Well again I kind of go back to my real life experiences. I have done some home improvements and so I had to be able to compute areas and volumes and do some work with angles to figure out how to lay in trim work and those kinds of things.

Each section of the transcripts that aligned with one of these categories was physically marked (circled) and assigned a number representing the category. Sections in the transcript that were left unmarked were reread, and if they still did not align with the three categories, they were put into a fourth category of other, which would be reanalyzed after the creation of code definitions.

The next step in the analysis was to shift to axial coding of the transcript to refine in what ways the three broad categories could be further delineated (Glaser & Strauss, 1967). Beginning with the category of mathematics knowledge, I created codes that would align with the research questions as well as capture responses that may inform the background of the second-career teachers. These codes were (Code A) responses related to connections among mathematical ideas and (Code B) connections to contexts outside of mathematics. All other references to mathematics not discussing mathematical connections were coded as Code C. For the second category, teaching, four codes were created for responses that included (Code D) connections among mathematical ideas in teaching, (Code E) connections to contexts outside of mathematics in teaching, and (Code F) variables that promote or inhibit the use of knowledge of mathematical connections in teaching. All other references to mathematics in teaching that did not include mathematical connections were coded as Code G. For the third category, prior experience, three codes were created for responses that discussed participant's initial career or other prior experiences: (Code H) use of or knowledge of connections among mathematical ideas and (Code I) use of or knowledge of connections with contexts outside of mathematics. All references to use of knowledge other than that of mathematical connections were coded as Code J.

Transcripts were then revisited and coded with these 10 codes. The coding process included circling and marking each section of the transcript with an appropriate code and keeping a separate record of where each code was used. There were instances of multiple codes applied to the same participant response. For example, during the interview with Meghan, I asked her to identify a particular or set of experiences that helped her to develop her knowledge of connections among mathematical ideas. Meghan responded,

> Well those types of things didn't occur to me until after I had been in the teaching field for maybe a couple of years or so. We started using clickers, have you heard of those? That kind of helped me make that connection and say okay that is something we really need to do is make sure that we are helping them keep current on old skills and that is also how you get kids caught up that haven't understood a concept previously is you help them revisit it and maybe revisit it in a new light.

Within this response, Meghan discussed the use of clickers in teaching (Code D) and supported her and her students' work with mathematical connections (Code A).

The last step in the analysis was to arrive at a means of organizing the coding across the transcripts. On the electronic copy of each transcript, I created a color-coding scheme for each of the 10 codes and then highlighted each section appropriately. A separate color was added to represent sections of the transcript coded with two or more codes. Then I created a separate document for each of the codes, cut and pasted each response aligning with that code or codes into the new document, and noted its source. As Miles and Huberman (1994) suggest, this type of summary supports "later and deeper analysis, while also clarifying your ideas about the meaning of your data" (p. 89).

Results

Although not all of the second-career mathematics teachers were able to exhibit knowledge of mathematical connections in every opportunity provided, results indicate that the majority of participants were able to exhibit knowledge of mathematical connections in several of the opportunities provided. When examining the results of the data analysis by participant, 11 of the 12 (92%) participants exhibited knowledge of mathematical connections on at least one occasion, and 10 of the 12 (83%) participants exhibited knowledge on at least four of the eight occasions. Moreover, five of the 12 (42%) participants exhibited knowledge of mathematical connections on five or more occasions, and five of the remaining seven participants (42%) provided two to four responses exhibiting knowledge of mathematical connections.

The next level of analysis of the questionnaires suggested at least two ways in which study participants' exhibited knowledge of mathematical connections. First, as a group, the second-career mathematics teachers were more likely to exhibit knowledge of mathematical connections to contexts outside of mathematics than knowledge of connections among mathematical ideas. More specifically, when a second-career teacher exhibited knowledge of one type of mathematical connections (usually knowledge of connections to contexts outside of mathematics), they were unlikely to exhibit the same level of knowledge of the other type of mathematical connection. Another way to frame this is that it may be that knowledge in one of the types of mathematical connections does not suggest knowledge in the other. Though the majority of second-career teachers exhibited knowledge of mathematical connections with contexts outside of mathematics more frequently, individual-level analysis also showed that three second-career teachers exhibited knowledge of connections among mathematical ideas more often.

Second, as a group, the second-career mathematics teachers were more likely to exhibit knowledge of mathematical connections when the situational opportunity was creating a mathematical

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problem (54%) than when evaluating a mathematical problem (40%). When looking across both the type of mathematical connection and situational opportunity, these second-career mathematics teachers were most likely to exhibit knowledge of mathematical connections when the connection was to contexts outside of mathematics and the situational opportunity was creating a mathematics problem (71%). This combination of situational opportunity and mathematical connection was almost twice as likely to result in a response exhibiting knowledge of a mathematical connection than the other options.

For those participants who exhibited knowledge of mathematical connections, they attributed this knowledge to sources such as teaching and the study of teaching rather than to their initial career experiences. For example Ronald stated,

> A lot of this came from, once I taught for a year or two we were in a master's program also, which is math education at Southern Connecticut State University so I was taking master's course work while I was teaching. That is where I would say some of the connections came. There is this class called teaching high school math from an advanced perspective or something like that where a lot of it was making connections and giving different representations of concepts.

Meghan, who spent four years as an engineer, voiced a very strong opinion about the way in which her initial-career experience influences her knowledge of mathematical connections to contexts outside of mathematics in instruction. She spoke about how the experiences in her initial-career did not support growth in her knowledge of mathematical connections to contexts outside of mathematics.

> Actually, my experience outside of teaching showed me how little math is really used in the real world. I don't say that lightly, I used more math in college to get my education than I did in the jobs that I was doing outside of college.

Mike, who spent 11 years as an actuary, was very cognizant of the disconnect he perceived between his initial career experiences and his knowledge of mathematical connections to contexts outside of mathematics.

Mike: Now that I have taken PhD course work, I have a much greater appreciation for those kinds of connections [connections to contexts outside of mathematics] and I did not before. Part of it might be that that masters program was really math content heavy and we didn't do a lot of area research on math ed and I was sort of pragmatic too, you know this is what seems to be working in classrooms as far as instruction and it was mostly math content like I said so that's why I didn't think of out of classroom context for connections.

Interviewer: You have spent twelve years in this actuarial experience...

Mike: Right, exactly. Applications of math concepts.

Interviewer: Right. It seems like that didn't naturally transition to the classroom thinking that way teaching wise.

Mike: I would say that's accurate. Yes.

Interestingly, Mike's perception of his own knowledge of mathematical connections to contexts outside of mathematics did not change through the use of mathematics in the real world, but instead by graduate work studying mathematics instruction. Mike explained that one reason that his initial-career experience did not inform his knowledge of mathematical connections related to teaching is because of how he "dichotomized the two things."

The participants who did exhibit knowledge of mathematical connections also appeared to struggle to apply their knowledge in teaching due to variables such as their perceptions of student ability and a depreciated view of the role of mathematical connection in mathematics pedagogy. For example, Rick stated,

> It is going to sound cliché because it's the same old well it sounds wonderful and a lot of people are on board with trying to do things in context and making connections, but at the same time there's also a lot of pressure to take care of the latest standardized test or SATs or where everybody else is kind of more immediate driver of what goes on in the school and that kind of depends on, that comes and goes on how much that kind of gets in the way or doesn't get in the way.

This quote points to pressures inhibiting the use of his knowledge of mathematical connections in instruction, but the comments also seem to suggest that making mathematical connections in instruction are somewhat extraneous and can be cut off if other priorities arise. This idea was echoed by a second subject of the study, Ronald.

> I'll be very honest here. I teach in an inner city high school where there is a significant gap in basic math skills among most of my students. I spend a lot of my time reinforcing basic skills like adding and subtracting positive and negative numbers, working with fractions etc., in the context of basic instruction in Algebra 1 and 2 topics. I sometimes use examples from my previous two careers (military and the telecom business)… But, with the |exception of very few students, these examples were well beyond where my students are with their math skills. I want to be careful that I don't give the impression that I believe my students are not capable of making connections. Not so. I just have a lot of work to do before I can get them there.

Ronald seems to be saying that the use of mathematical connections in his teaching would require a level of mathematical knowledge his students do not yet possess.

Implications

That these second-career mathematics teachers were able to exhibit knowledge of mathematical connections but encountered difficulty integrating this knowledge into their instruction is an important finding. Particularly, this study illustrates that it may not be second career mathematics teachers' lack of knowledge that is of issue. Rather, the issues may be assisting the second-career teacher to make clearer the connection between their own career experiences and the classroom. Data from this study suggests that efforts made by university preparation programs may need to further examine to what extent they are balancing content and pedagogy. Evidence of this may be seen in the way Mike spoke about the difference experiences between his masters and PhD work.

An additional issue inhibiting the integration the use of second-career teachers' knowledge of mathematical connections may be the way in which these teachers perceive the role of developing

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students' knowledge of mathematical connections in mathematics instruction. Evidence for this can be seen in the way in which Ronald and Rick both spoke about the integration of mathematical connections and their concern over student knowledge as well as bureaucratic pressures. This is an encouraging finding, as the perceptions of second-career mathematics teachers can be challenged in their preparation program and supported during their teaching with resources from professional organizations such as the National Council of Teachers of Mathematics, the National Science Teachers Association, and the National Research Council as well as through the examination and use of curricula that develops students' knowledge of mathematical connections as an integrated component of mathematics instruction (e.g., University of Chicago School Mathematics Project).

Although the focus of this study was on second-career mathematics teachers, the results may be extended to other STEM second-career teachers. Several of the participants of this study came from professions whose experiences may also provide connections to teaching the subjects of chemistry (chemist), physics (engineer), or computer science (web development). The way in which participants in the study encountered difficulty integrating connections between their prior career experiences and teaching may be mirrored in a similar way in these subject areas.

The participants in this study represent only a subset (a substantial subset) of the teaching population; however, the results of the study may also be informative for those who prepare teachers through a more traditional route. In Ma's (1999) study of Chinese and American teachers, the Chinese teachers referred to mathematical connections among mathematical ideas as a "'knot' that ties a cluster of concepts that support the understanding of the meaning" of a mathematical topic (p. 82). This is a goal not specific to those entering teaching from mathematically oriented initial careers. The results of this study may also impact the ongoing assessment question regarding how to identify what constitutes evidence of knowledge of mathematical connections (in general and specific to various types of mathematical connections). Translating this view into a rubric to identify a response that qualifies as a mathematical connection is a complex process and the methods used in this study could continue to shed light on this issue. Given that more effective definitions of mathematical connections still need to be developed, further work aimed at expanding and refining a measurement tool is an important next step for research about teachers' knowledge of mathematical connections.

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