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PRESERVICE TEACHER LEARNING TO HELP ELLS MAKE SENSE OF MATHEMATICS

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This study investigates how preservice teachers (*PST*) *help English language learners* (*ELLs*) *understand cognitive demanding mathematical problems using complicated language use. Three mathematics PSTs worked with ELLs in one-on-one settings while receiving individual interventions. The strategies they implemented were analyzed based on four categories: mathematical content, culture/life experience, mathematical/cognitive process, and mathematical/contextual language. As time evolved, all of the PSTs began to integrate life-connection strategies and various visuals that are closely related to mathematical situations, which they learned during the interventions. This study suggests that PSTs require significant preparation infused with practical experiences and examples in order to design a linguistically and conceptually rich lesson.*

Introduction

Although teacher educators and researchers (e.g., Artiles & McClafferty, 1998; Durgunoglu & Hughes, 2010) have contended that teacher preparation programs should include rigorous English language learner (ELL) related education to help narrow the achievement gap, there has been little attention how to teach ELLs in mathematics (Janzen, 2008). This is perhaps guided by the misconception that mathematics is less difficult for ELLs because it is based on a universal language of numbers. However, ELLs have significant difficulty in mathematics classrooms because "mathematics education involves terminology and its associated concepts, oral or written instructions on how to complete problems, and the basic language used in a teacher's explanation of a process or concept" (Echevarria, Vogt, & Short, 2010, p. 1). With the linguistic demand that is innately part of the instructional context, teachers also have to accommodate cultural and socioeconomic factors associated with cognitive activities (Campbell, Adams, & Davis, 2007). Responding to these current challenges in the field, as well as research recommendations, I designed a study to investigate how preservice teachers (PSTs) learn to help ELLs understand mathematical problems.

Purposes of the Study

The primary research focus of this study was PST learning for the ultimate purpose of designing an effective model of ELL education within mathematics teacher preparation programs. This study also seeks to investigate PSTs' thinking, planning, and use of strategies to help ELLs make sense of cognitive demanding mathematical problems, which are embedded with sophisticated language. The specific question of this study is what strategies middle school PSTs implement to support ELLs with making sense of cognitive demanding problems while they learn research-based ELL pedagogies.

Perspectives

Researchers (e.g., Chval & Chavez, 2011; Celedon-Pattichis & Ramirez, 2012) have suggested ELL teaching strategies by reviewing various ELL studies. Some common recommendations include connecting mathematics to life experiences, using visuals, providing challenging tasks, building linguistically sensitive social environment, and considering cultural and linguistic differences as intellectual resources. Moreover, Vomvoridi-Ivanovic and Chval (2014) argue that PSTs must learn the linguistic and cultural demands and needs in teaching and learning mathematics. Aligned with this perspective, several researchers (Downey & Cobbs, 2007; Fernandes, 2011; Pappamihiel, 2007) conducted empirical studies about PST learning to teach ELLs and they found that having experience with ELLs enables PSTs to reconsider their perspectives. However, according to de Araujo et al. (2015), merely providing fieldwork opportunities with ELLs does not make a significant difference when PSTs teach mathematics to ELLs. The results of this study imply PSTs need to receive structured coaching in order to integrate ELL strategies in mathematical instruction effectively.

Conceptual Framework

The problem space model (Campbell, Adams & Davis, 2007) was adapted to construct the framework for this study (Figure 1). The model was extended from the constructive model of mathematics teaching (Simon, 1995) to design a course for PSTs about how to teach problem solving for ELLs. Various theories were adopted such as theories of language and culture (Cuevas, 1984; Echevarria, Vogt, & Short, 2004), socio-cultural approach to mediated action (Wertsch, 1991), and cognitive load theory (van Merriënboer & Sweller, 2005).

This model explains that the problem space is created when a solver reads a problem and analyzes the mathematical situation based on *mathematical knowledge* and *cultural/life experiences*. Identifying the *mathematical/cognitive processes* and understanding *mathematical/contextual language* are followed in order to build a plan to solve. Strategies emerge during interactions with the solver's experiences related to the context of the mathematical problem. Understanding the context and finding proper strategies eventually yield the decision of how to use related mathematical content. Therefore, mathematics teachers need to consider how prior knowledge and life experiences, which are implied in the language and situations used in the context of mathematical problems, may not correspond with students' experiences, especially with ELLs.

Methods

Participants and Setting

Three white female middle school mathematics PSTs (Becky, Lucy, and Kate; pseudonyms) who were enrolled in a university-based teacher preparation program participated in this case study. None of them had experience teaching ELLs or received any ELL-focused training. Each PST was assigned to a middle school student who was identified as an ELL by their school administration. All of the PSTs were asked to prepare a lesson based on a given problem for ELLs and worked with their assigned ELLs for five weeks. After each weekly session, I interviewed the PSTs and provided interventions (Table 1) about research-based ELL strategies (Chval & Chavez, 2011).

Problem Selection

Cognitively demanding mathematical problems were selected by considering their content level and assessing it using the criteria created by Smith and Stein (1998). Five mathematical problems were chosen from the released items of the Smarter Balanced Assessment Consortium (SBAC), the Partnership for Assessment of Readiness for College and Careers (PARCC), the Program for International Student Assessment (PISA), and the National

Assessment of Educational Progress (NAEP). The first week problem adapted from SBAC is "Claire is filling bags with sand. All the bags are the same size. Each bag must weigh less than 50 pounds. One sand bag weighs 58 pounds, another sand bag weighs 41 pounds, and another sand bag weighs 53 pounds. Explain whether Claire can pour sand between sand bags so that the weight of each bag is less than 50 pounds."

Data Collection and Analysis

Written lesson plans, pre and post interviews, video records of implementation, artifacts, written reflections, and pre and post surveys were collected for five weeks. In addition, *the constant comparative analysis method* (CCA method; Fram, 2013) was employed for data analysis. This method is used to constantly compare one set of data with another through open coding, axial coding, and selective coding. I followed this basic procedure, but I used NVivo (Mac version 10) in order to conduct an effective video coding. First, I watched and open coded the data of the first case and I established a codebook draft based on the result of open coding and the five categories of the conceptual framework. Using the draft, I coded other cases with continuous comparing and revised the codebook whenever I complete coding each case. After I finished coding all cases, I finalized the codebook and conducted axial coding and selective coding. Table 2 is a part of the codebook, which I used for one of the five categories, *cultural/life experiences*. The codes were determined based on teaching strategies the PSTs used. In order to analyze teaching patterns and sequential changes associated with interventions, I built a node matrix (code matrix) between each PST's implementations and codes of each category (Figure 2). In Figure 2, the left most column represents data sources and the top row includes the codes related to *mathematical/cognitive processes.* The numbers in each cell represent the frequency of each strategy.

Results

Table 3 summarizes how each PST implemented strategies and reveals that the strategy all PSTs consistently used was *visuals*.

Strategies Used for Making Sense of Problems

The main concern of the PSTs in preparation phase was how to modify the problems, such as simplifying the language, adding visuals, and adding extra questions. However, they sometimes lessened the cognitive demand by removing a problematic aspect from the problems, or they emphasized procedures rather than the reasoning or a conceptual understanding (Stein et al., 2009). Moreover, life and cultural connections were usually not considered in the lesson preparation, especially in the early weeks.

Visuals were commonly used during implementation because the PSTs believed visuals effectively deliver information even though students may not always comprehend the language. Hence, visuals were utilized frequently to explain the meaning of a problem or as a communication tool (Chval & Chavez, 2011; Moschkovich, 2002; Raborn, 1995). However, this strategy was not always successful because the PSTs sometimes chose an inappropriate image that did not convey a sufficient amount of information or confused their students. As an alternative communication tool, their use of visuals was also limiting because the ELLs barely initiated a way to express their thinking. Rather, they tended to imitate what their teachers had shown through the visuals. Besides visual aids, the PSTs needed to explain the meaning of words that had different general and mathematical meanings (Chval & Chavez, 2011; Moll, 1988, 1989). Interestingly, this process seemed to be an obstacle for the PSTs because they were not prepared to explain such meanings. Lucy confessed this lack of preparation in her post-survey, asserting "the greatest challenge in teaching mathematics to ELLs was explaining terms and words that they weren't familiar with. Some of the words that I use in everyday language are difficult to explain to people who do not know what they mean" (Lucy, post-survey). As a native English speaker, it was difficult for her to identify what words might be confusing to ELLs who do not share a similar culture or similar life experiences with her. Specifically, when the ELLs struggled to understand the problems or their teachers' explanations, the PSTs had to grapple with employing unplanned strategies spontaneously. As a result, many of their unplanned attempts were not successful, and more often than not, they ended up telling their students what procedures they should take.

Changes in Supports for ELLs

It was evident that there were many individual differences among the three PSTs in terms of adopting research-based strategies. Nevertheless, one positive result present in each case was that they began to apply life-connection strategies after they learned it from the researcher. Another significant influence from interventions occurred in the way visuals were used by the PSTs. They integrated more diverse types of visuals that possessed deeper relations with mathematical situations into their lessons after they learned visuals should be used in mathematically meaningful ways. Moreover, it should be noted that none of the PSTs clearly identified strategies for ELLs in the beginning of the study. After the weeks of focused interventions, however, they were able to recognize more specific ELL strategies and provide more detailed explanations in their lesson plans than they did in the beginning. In addition, they were able to ask more open-ended questions and maintain the high-level cognitive demands of the problems.

Conclusions

The results of this study indicate that learning ELL pedagogies in a structured manner, as well as having practical experience with teaching ELLs, is essential for PSTs to develop effective pedagogy for ELLs in mathematics education. The ELL strategies the PSTs adopted before they learned research-based strategies were simplifying language and adding contextual pictures, which significantly reduced the high-level cognitive demands from the problem or did not provide enough effective support. Meaningful applications came after the PSTs learned the research-based strategies, especially when they saw specific examples. Therefore, teacher educators should provide PSTs with concrete and specific examples concerning the general guidelines of ELL education.

Designing a linguistically and conceptually rich lesson in order to make it accessible to ELLs is an important skill for all teachers of ELLs. Hence, PSTs have to develop this skill in their preparation programs and understand that they have to consider not only mathematical knowledge but also cultural and linguistic demands experienced by students. In this sense, this study has a crucial link to PST education and introduces a model for PST preparation on how to teach mathematics for ELLs. Working one-on-one with ELLs prior to their student teaching helps PSTs have tangible and specific knowledge about teaching ELLs, as well as heighten their competence in working with diverse students. This type of preparation can be accomplished by concurrently providing interventions that enable PSTs to apply the ELL strategies, introduced during the interventions, to effectively teach a specific mathematical concept to a population of ELLs.

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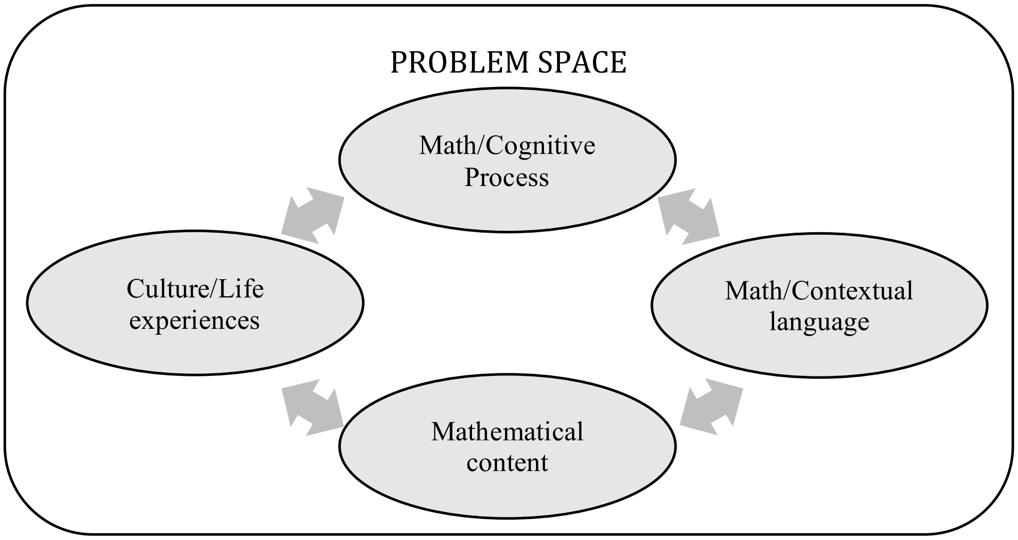

Figure 1. Interactions in the Problem Space (Adapted from Campbell et al., 2007, p. 9)

Table 1. Weekly contents of the PST Interventions

	Focused Topic	Activity
1	Needs of ELLs	Read a story of a Korean ELL
2	Connect mathematics with life experiences and existing knowledge	Discuss how to begin an activity with life connections and students' prior knowledge
3	Visual supports	Analyze examples of using visuals
4	Rich environments in mathematics and language	Use a Venn diagram to discuss how linguistic and mathematical strategies are related
5	Revisit the connection topic of week 2	Compare and analyze examples of teacher-student dialogues in terms of connection between mathematics and students' or a student's life experiences

Table 2. A sample of codes and descriptions of the category of cultural/life experiences

	Cultural/Life experiences	
ALE	Assess a student's life experience	Assess a student's prior life experience relevant to a mathematical problem before or during the problem-solving process
CTC	Connect to a student's culture	Change the context to align with the Korean culture or connect a mathematical problem with Korean culture
CTL	Connect to a student's life experience	Change the problem context to align with a student's life experience or connect a mathematical problem with a student's life experience
ECC	Explain cultural context	Teach or describe cultural aspects in the problem context, which might be different from student's culture

Table 3. ***Patterns of the strategies PSTs applied to help ELLs make sense of the problems.***

	Becky	Lucy	Kate
Strategies used consistently	Assessing math knowledge Modifying language Visuals	Analyzing problems Assessing math knowledge Visuals	Rephrasing Visuals
Strategies used none/little	Cultural connection Multiple solutions	Modifying language Sentence frame	Cultural connection Assessing English Sentence frame
Strategies influenced from interventions	Life connection Visuals	Cultural connection Life connection Visuals	Visuals

	A : AAP -...	B : FPA -...	C : GSP -...	D : MSS -...	E : PES -...	F : PIT - P...	G : RPC -...	H : SMS -...	I : UMR -...
1 : Lucy1_091614 (pre-inter...	0	0	0	0	0	0	0	0	0
2 : Lucy1_091614 (Teaching)	2	0	1	1	10	0	1	0	3
3 : Lucy1_LP	0	0	0	0	0	0	0	0	1
4 : Lucy2 092314 (pre-inter...	0	0	0	0	1	0	0	0	0
5 : Lucy2 092314 (Teaching)	9	1	2	2	35	0	0	4	2
6 : Lucy2_LP	0	0	0	0	0	0	0	0	0
7 : Lucy2_LP procedure	0	0	0	1	0	0	0	0	0
8 : Lucy3_093014 (pre-inter...	1	0	0	0	0	0	0	2	0
9 : Lucy3_093014 (teaching)	8	0	4	1	17	0	0	2	0
10 : Lucy3_LP	0	0	0	0	0	0	0	0	0
11 : Lucy3_modified problem	0	0	0	0	0	0	0	0	0
12 : Lucy4_100714 (interactive)	3	0	1	1	12	0	0	2	0
13 : Lucy4_100714 (preactive)	0	0	0	0	0	0	0	1	0
14 : Lucy4_LP	0	0	0	0	0	0	0	0	0
15 : Lucy4_modified problem	0	0	0	0	0	0	0	0	0
16 : Lucy5_101414 (interactive)	5	0	1	0	11	0	0	2	3
17 : Lucy5_101414 (preactive)	0	0	0	0	0	0	0	0	0
18 : Lucy5_LP	0	0	0	0	0	0	0	0	0
19 : Lucy5_modified problem	0	0	0	0	0	0	0	0	0

Figure 2. A sample node matrix of Lucy's case