ANALYZING A DISCOURSE OF SCAFFOLDS FOR MATHEMATICS INSTRUCTION FOR AN ELL WITH LEARNING DISABILITIES

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In this case study, we examine the usage of language — how teachers used and regulated their language when teaching English language learners (ELLs) with learning disabilities (LD) how to solve mathematics multiplication problems. We focus on types of scaffolds used by teachers to identify how scaffolding helps ELLs with LD build better multiplicative reasoning. Using an exploratory case study, we find that more linguistic scaffolding and small group interactions are beneficial for ELLs with LD. In combination with kinesthetic scaffolding, they form an effective instructional method for improving multiplicative reasoning among ELLs with LD.

Keywords: Classroom Discourse, Number Concepts and Operations, Mathematical Knowledge for Teaching, Elementary School Education

Introduction

According to the section on English language acquisition in Title III of the Elementary and Secondary Education Act (ESEA) reauthorized by the Every Student Succeeds Act (ESSA) in 2015, schools are required to be accountable for the improvement of all children, including those with "disability, recently arrived ELLs, and long-term ELLs" (Non-Regulatory Guidance, 2016, p. 4). Students with limited English proficiency or what ESSA now refers to as English Learners (ELs) must also meet benchmark goals as a subgroup for passing achievement goals (pass/do not pass) and making adequate growth annually in mathematics. In order to meet district and school accountabilities requirements for dually classified ELLs (ELL and special education), it is necessary to provide appropriate support and interventions in a timely manner to promote their academic performance and address persistent achievement gaps in math (Zhou, 1997).

Math Problem-Solving Skills and Literacy Skills

Good literacy skills, which include reading, reading comprehension, and technical reading skills, play a significant role in students' ability to solve math word problems efficiently, especially for students who have good calculation ability (Kyttälä & Björn, 2014). According to findings from previous studies, reading fluency predicts student performance in solving mathematical word problems (Vilenius-Tuohimaa et al., 2008; Kyttälä & Björn, 2014). In addition, Cummins et al. (1988) showed that children sometimes make mistakes on math word problems due to ambiguous language in the problem statements or miscomprehension of the verbal instructions, shaped by their level of English proficiency.

Content in an Academic Setting

ELL students experience a complex process with challenging academic content along with academic proficiency in language (Gerena & Keiler, 2012). Although ELLs may appear to be verbally fluent in English, they are still struggling with complex academic material that requires the production of specific academic discourse (Gerena & Keiler, 2012; Olsen, 2010) that differs

from social language use.

Scholars in the field have researched and recommended the use of instructional scaffolds to convey meaning to students at varying levels of English proficiency, which include visual/graphic scaffolding, linguistic scaffolding, interactive scaffolding and kinesthetic scaffolding (Gibbons, 2014; Gottlieb, 2016). These scaffolds are important considerations in the planning of math instruction for dually classified ELLs (DC ELLs) (McGhee, 2011).

Scaffolding

In the teaching-learning framework, scaffolding is a central notion adapted from Gibbons (2002, 2014) which is supported by a constructivist theory of learning. Scaffolding is a support to "enable children to perform tasks independently that previously they could perform only with the assistance or guidance of the teacher" (Gibbons, 2002, p. vii). Scaffolding uses the theoretical framework that Halliday (1993) highlighted about registers of language through the classroom interaction of teachers and students working together to develop "new skills, concepts, and levels of understanding" (Gibbons, 2002, p. vii). Gibbons (2002, 2014) also suggested that scaffolding can be used for English language teaching to ELL students in mainstream classrooms, where they spend the majority of their school day.

Scaffolds are strategies that support the delivery of target content with an explicit inclusion of a given scaffold appropriate for each ELLs' level of English proficiency and, in this case, the added dimension of a learning disability. Gottlieb (2016) describes four types of instructional scaffolds that teachers can use and students can appropriate to create understanding around target content. These scaffolds include visual, linguistic, interactive and kinesthetic scaffolds (Gottlieb, 2016).

Visual scaffolding. Visual scaffolding helps ELL students by using drawings or photographs to connect English words to visual images and assists ELL students in learning the subject. This approach makes complex ideas feel more accessible to students and makes language more memorable, all while providing comprehensible input of the target content (McCloskey, 2005, p. 1). There are a variety of instructional supports that can build students' visual experience in the classroom, including manipulatives, real objects, and multimedia material (Carrasquillo & Rodrigues, 2002; Gottlieb, 2012).

Linguistic scaffolding. Linguistic scaffolding can be conceptualized according to the zone of proximal development (Vygotsky, 1978). Teachers must provide effective and responsive support for students' language output performance, which requires teachers to use language that is comprehensible to students when providing them with new and more sophisticated knowledge, including using a slower rate of speech or simplified vocabulary with consistent reinforcement of a target set of words (Gibbons, 2003; Bradley and Reinking, 2011).

Interactive scaffolding. As mentioned above, Heath (1982) described a "literacy event" as "any occasion in which a piece of writing is integral to the nature of participants' interactions and their interpretive processes" (p. 438). Moreover, Goffman (1993) put forward the idea of "interactionism," which relates "only to those aspects of 'context' that are directly observable and to such immediate links between individuals as their 'roles,' 'obligations,' 'face-to-face encounters,' and so on" (p. 439). An example of instructional support for both students and teachers is using active roles in pair work and small group work (Gibbons, 2008).

Kinesthetic scaffolding. Asher (1969) first introduced a strategy called *Total Physical Response Technique*, which directly relates to kinesthetic scaffolding. This approach requires the students to listen to a foreign language command and obey it using a physical action immediately with no expectation of speech production (Asher, 1969). Brand et al. (2012) suggested that

students who use kinesthetic scaffolding can benefit from "sign language, translation into another language, gestures" during sessions (p. 139), while not being restricted from participating due to their lower levels of English proficiency.

In this paper, we apply four different kinds of scaffolding to analyze the mathematics instructional discourse exchanges between a teacher and an ELL student with LD within the context of a small group constructivist-oriented learning environment. We intended to answer following research questions:

1. What types of scaffolds do teachers and dually classified ELLs make in multiplicative reasoning during instruction and assessment activities?
2. How do teachers regulate language usage and scaffolding to facilitate the multiplicative reasoning of ELLs with LD?

Research Methodology

This exploratory case study investigates the interplay between teacher and student in mathematics instruction from a constructivist perspective of learning (Vygotsky, 1962). Constructivism is a philosophy of learning that focuses on individuals actively participating in learning rather than passively receiving knowledge (Gunning, 2010). In this perspective, the learning process can only occur when the learners are actively engaged in integrating new knowledge with existing knowledge (Morrow & Tracey, 2012). Therefore, constructivist theory will be the research framework for our analysis of teacher-student discourse.

Mode of Inquiry

We use an exploratory case study to examine the scaffolds used by teachers and appropriated by dually classified ELs. In light of the research process, Yin (2014) defined a case study as "an empirical inquiry that investigates a contemporary phenomenon (the 'case') within its real-life context, especially when the boundaries between phenomenon and context may not be clearly evident" (p. 16). The researcher-teacher (a math educator/ university professor) worked with an ELL student with LD and another native English speaker with LD in each session. The teacher used the constructivist teaching experiment method (Cobb & Steffe, 1983; Steffe, Thompson & von Glasersfelf, 2000) with the team of students.

Setting and Context of the Study

This study was conducted within the larger context of a National Science Foundation (NSF) funded project (Xin et al., 2008). This study took place at a local elementary public school resource room in the Midwestern United States. The participant attended 26 weekly teaching sessions of 25-35 minutes in pairs with another non-ELL student with LD. Each day, the math teacher worked with the pair of students together. Each lesson was designed based on an assessment of the student's level of understanding of the given math content from the previous session. The study was conducted over a period of eight months. Each session, the instructor provided a pedagogical approach to promote the ELL's progress toward multiplicative reasoning (Tzur et al., 2010) and problem solving (Xin, 2012).

Participants

The participants were selected from a local elementary school in the Midwestern United States. This study worked with students during an after-school program. The participants for this study were a fifth-grade ELL student with learning disabilities (Eliza) and a fifth-grade native English speaker with learning disabilities (Leslie). According to Eliza's IEP, she was included in a general education class setting for 50% of the time, and received 45 minutes of math instruction in the resource room each day from different math instructors. Eliza was placed in a

learning support classroom for reading, English language arts, and math. Eliza's intellectual functioning was in a very low range (IQ (OTIS) full scale is 69 with a verbal score of 69). Eliza has been placed in the special education program each of the past four years. The fifth-grade native English student (Leslie) worked as a group partner with Eliza during each session.

Data Sources

The sources of data were teaching videos and field notes taken during instructional observations. The teaching videos recorded the teacher and focal students, and the field notes were taken by graduate students. We included the transcripts and corresponding field notes for five out of the seven recorded teaching sessions. The rationale for including only those sessions was due to availability of the data.

Data Analysis

We coded both the instructor's discourse and the ELL student's problem solving and reasoning. The approach was coding the discourse moves of the discourse between the teacher and the student. The coding method we used was coding in terms of four different scaffoldings: visual/graphic scaffolding, linguistic scaffolding, interactive scaffolding and kinesthetic scaffolding. The purpose of this coding method was to answer the first research question and try to find the most successful scaffold that the math teacher used for ELL students with LD, which is the main purpose of this study.

Coding Scheme of Discourse Moves

We used NVivo 11 to transcribe and code the verbal and nonverbal mathematical communication for both the teacher and the pair of students (one of them, Eliza, is our participant) (Xin et al., 2016), as well as their behavior (e.g., using finger counting, creating the mathematical model on scratch paper). We did not transcribe unrelated mathematical verbal or nonverbal communication or behavior as it was not central to our inquiry.

Using the coding scheme, we coded each transcript by the type of scaffolding, including visual /graphic scaffold, interactive scaffold, linguistic scaffold or kinesthetic scaffold for both students and the teacher discourse (Table 1).

Moreover, in order to analyze the linguistic scaffold, we adopted the concordance software AntConc 3.4.3w (Windows) 2014. AntConc is a useful tool for analyzing a detailed corpus in linguistic research (Lei, 2016). After obtaining the organized discourse coding transcripts from Nvivo, we imported them into AntConc to analyze the frequency of the teacher's language in session transcripts by counting the four categories, such as "How many towers?" "How many cubes?" "How many more?" and "PGBM" (Please Go and Bring Me), which were the major activities involved in the constructivist-oriented learning of multiplicative reasoning (Xin, Tzur, and Si, 2008).

Table 1: Scaffolding Coding Scheme

Scaffolds	Teacher	Students
Visual/Graphic Scaffold	"Please generate a model of 5 towers of 9 on the grid ½ sheet."	"Can I use paper to double-check?"
Interactive Scaffold	The teacher helps E with the arithmetic and shows her the error she made—now E has 45.	The teacher asks S to help E and he does. S counts towers for E until S shows 5 with his hand.
Linguistic Scaffold	T: How many cubes do you already know are in a tower? L: 6 T: How many towers in all? E: 5	L: How many cubes in each tower? E: 5 L: How many towers? E: 6
Kinesthetic Scaffold	"Use my finger to keep track of it. And we can use our fingers if it is helpful. Here it is very helpful because you can keep track how many groups you have."	"I counted with my fingers."

In addition, we defined the interactive scaffolds by three characteristics: teacher-student interaction, student-student interaction and small group interaction (Table 2).

Table 2: Interactive Scaffolds

Teacher-student interaction	Student-student interaction	Small group interaction
The teacher helps E with the arithmetic and shows her the error she made—now E has 45.	The teacher asks S to help E and he does. S counts towers for E until S shows 5 with his hand.	T: How many cubes in all? E: 28 T: OK. What did you get on the calculator? (to L) L: 44 (with calculator)

Findings

In the first stage of analysis, we report the frequency results for the scaffolds used by the teacher and appropriated by the student (Eliza). The highest frequency of scaffolds used by the student and the teacher were kinesthetic scaffolds, while the second highest amount was interactive scaffolds (Figure 1). The teacher often used finger counting to help students do multiplication to solve the different types of problems, such as unit rate (UR) (e.g. "how many cubes in each tower"), composite units (CU) (e.g. "how many towers") and 1's (e.g. "how many cubes in all") (Tzur et al., 2010). Students in these sessions often used finger counting to show a finger trick for multiplication with numbers. Below is an example exchange between Eliza (E) and teacher (T).

Excerpt 1 (December 11, 2008)

E: 7 plus 7 equals 14 for 2 towers. She counted 15, 16, 17… (Finger counting)
(Counted up to 34. She tries to keep track with her fingers and wanted to be at seven fingers when she had her answer.)
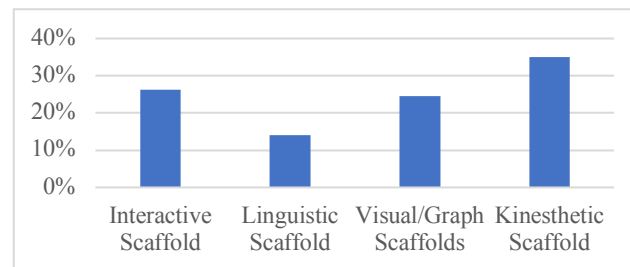
T: (prompt) Write down the number of cubes you got.

E: I lost count.

T: Try again. Do you want to use my fingers?

E: Yes. (counts the towers, 1, 2, 3, 4, 5, 6, 7, 8, 9, 1 finger/tower… 10, 11, 12 …

T: (Explains the trick to E use fingers)

Figure 1. Frequency of Scaffolds across students and the teacher

As shown in this example, the teacher prompted to get Eliza's method and Eliza tried to use both her fingers and the teacher's fingers to solve the problem. We can find that in this situation, the teacher and the student had an effective interaction, and then the teacher could express the method that should be used for these types of problems. Therefore, Figure 2 shows the different types of interaction that the teacher and student used in sessions. It indicates that the teacher preferred to use small group interaction during the sessions, and students had more interaction during group work with both classmate and teacher. For example, the following excerpt is from a transcript between the teacher (T) and students Eliza (E) and Leslie (L).

Excerpt 2 (February 17, 2009)
T: Question number one
L: How many cubes in each tower?
E: 5
L: How many towers?
E: Six
T: Six what?
E: Six cubes.
L: How many cubes... in each
E: 5
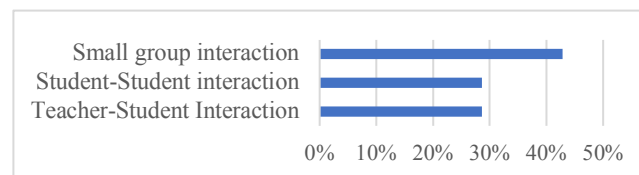*L*: How many in all?
T: How many what?
L: How many towers in all?
E: Six.
T: I think the question you're looking for is how many cubes in all. Can you ask it?
L: How many cubes in all?
E: 30

Figure 2. Frequency of scaffolding used by interaction types

The example above shows that the ELL student Eliza answered the native English speaker using different types of questions (Unit Rate [UR, Xin, 2012] and Composite Unit [CU]) in an interactive way to help each other understand the three basic elements (i.e., UR, # of Units, and Product) in elementary multiplicative problem solving. Also, the teacher was involved in the

student-student interaction to ensure the accuracy of their linguistic usage and to check their understanding (such as "how many what?").

Using AntConc, we found that in the session transcripts the teacher used the phrase "how many" 111 times, while "how many towers" was used 18 times, and "how many cubes" was used 37 times. Another key word that the teacher frequently used was "PGBM" or "Please Go and Bring Me," which is the main task of a turn-taking 'platform' game PGBM (Xin et al., 2008). The authors created this game and used a simple language to name it and make it easier for ELLs with LD. The frequency of the language used by the teacher indicates that "PGBM" was used more and more often to engage the ELL in learning multiplicative reasoning and problem solving (e.g. "PGBM a tower of eleven," "PGBM six cubes").

Conclusions and Implications

In response to our research questions and in terms of the findings from our analysis, we draw the following conclusions:

1. The types of scaffolds that the teacher made in multiplicative reasoning to scaffold instruction for an ELL with LD are interactive, linguistic, visual/graphic and kinesthetic scaffolds. Among these, the kinesthetic scaffold was the most frequently used by the teacher. The teacher used finger counting as a method to show the student how to solve composite units (CU) and unit rates (UR). The second highest scaffold frequency was interactive scaffolding. We redefined and divided interactive scaffolding into three characteristics: student-student interaction, teacher-student interaction and small group interaction. The results show that small group interaction is the most effective and useful interaction that was used among the students and the teacher. Students, particularly Eliza, in the small group demonstrated a greater willingness and capacity to think and answer multiplication problems.
2. When the teacher taught multiplicative reasoning to the ELL with LD, he frequently used simple phrases such as "how many" and "PGBM." The rationale of using the linguistic scaffolding is that the teacher repeatedly used and also let students repeatedly use the simple phrase "how many" to illustrate the process of thinking and solving multiplication problems. In addition, "PGBM" characterizes the "platform" game used, which also benefits English language learners to get directions promptly and attend to multiplicative reasoning.

In general, we found that the four scaffolds in classroom discourse that the teacher frequently used with students can influence the multiplicative reasoning of the English language learner with learning disabilities and improve mathematical problem-solving achievement. We also found that kinesthetic scaffolding is the most direct method tied with helping the ELL with LD solving multiplicative problems. However, in order to better serve English language learners with LD, especially in the classroom environment, teachers should focus on better linguistic scaffolding usage within small group interactions. In our future research, we will analyze the level of intellectual work (Xin et al., 2016) done by the teacher and the students through determining how the four scaffolds promote students comprehend multiplicative reasoning at the abstract level, in particular, to meet the challenging math curriculum standards.

Acknowledgements

References

Archer, A., & Hughes, C. A. (2011). *Explicit instruction: Efficient and effective teaching*. New York, NY: Guilford Publications.

Biber, D., Conrad, S., & Reppen, R. (1998). *Corpus linguistics: Investigating language structure and use*. Cambridge University Press.

Bishop, J. P., & Whitacre, I (2010). Intellectual work: The depth of mathematical discourse and its relationship to student learning. In P. Brosnan, D. B. Erchick, & L. Flevares (Eds.), *Proceedings of the 32nd Annual Meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education* (pp. 401–409). Columbus, OH: The Ohio State University.

Bradley, B. A., & Reinking, D. (2011). A formative experiment to enhance teacher-child language interactions in a preschool classroom. *Journal of Early Childhood Literacy*, *11*(3), 362-401.

Brand, T., S., Favazza, A. E., & Dalton, E. M. (2012). Universal design for learning: A blueprint for success for all learners. *Kappa Delta Pi Record*, *48*(3), 134-139.

Every Student Succeeds Act, Pub. L. No. Public Law 114-95 (2015 December 10, 2015).

Gerena, L., & Keiler, L. (2012). Effective intervention with urban secondary English language learners: How peer instructors support learning. *Bilingual Research Journal*, *35*(1), 76-97.

Gibbons, P. (2014). *Scaffolding language, scaffolding learning: teaching English language learners in the mainstream classroom* (2nd ed.). Portsmouth, NH: Heineman.

Gibbons, P. (2002). *Scaffolding language, scaffolding learning: Teaching second language learners in the mainstream classroom*. Portsmouth, NH: Heinemann. Wood, K. C., Smith, H., & Grossniklaus, D. (2008). Piaget's stages. Retrieved November, 20.

Gottlieb, M. (2016). *Assessing English Language Learners: Bridges to Educational Equity: Connecting Academic Language Proficiency to Student Achievement*, 2nd Ed. Thousand Oaks, CA: Corwin.

Gottlieb, M. (2013). *Essential Actions: A Handbook for Implementing WIDA's Framework for English Language Development Standards*. Madison, WiDA Consortium.

Gunning, T. G. (2010). *Creating literacy instruction for all students*. Boston, MA: Pearson.

Heath, S. B. (1982). What no bedtime story means: Narrative skills at home and school. *Language in society*, *11*(1), 49-76.

Kingsdorf, S., & Krawec, J. (2016). Assessing a multi-component math intervention within a cognitive-behavioral framework on the word problem-solving responses of a diverse group of third graders. *Cogent Education*, *3*(1), 1160638.

Kyttälä, M., & Björn, P. M. (2014). The role of literacy skills in adolescents' mathematics word problem performance: Controlling for visuo-spatial ability and mathematics anxiety. *Learning and Individual Differences*, *29*, 59-66.

Lei, Q. (2016). A research of English article errors in writings by Chinese ESL learners. *English Language Teaching Ideas Journal*. 2016.

McCloskey, M. L. (2005). Visual scaffolding to support ell reading. *Keeping the Promise*, 1-7.

Morrow, L. M., & Tracey, D. H. (2012). *Lenses on reading: An introduction to theories and models*. Guilford Press.

Street, B. V. (Ed.). (1993). *Cross-cultural approaches to literacy* (Vol. 23). Cambridge University Press.

Swales, J. (1990). *Genre analysis: English in academic and research settings*. Cambridge University Press.

Tzur, R., Xin, Y. P., Kenney, R., & Guebert, A. (2010). Students with Learning Disability in Math Are Left Behind in Multiplicative Reasoning? Number as Abstract Composite Unit is a Likely 'Culprit'. *Online Submission*.

Vygotsky, L. S. (1978). *Mind in society*: The development of higher mental process.

Vygotsky, L. S. (1962). Language and thought. *Massachusetts Institute of Technology Press*, Ontario, Canada.

Xin, Y. P. (2012). *Conceptual model-based problem solving: Teach students with learning difficulties to solve math problems*. The Netherlands: Sense Publishers.

Xin, Y. P., Liu, J., Jones, S. R., Tzur, R., & Si, L. (2016). A preliminary discourse analysis of constructivist-oriented mathematics instruction for a student with learning disabilities. *The Journal of Educational Research*, *109*(4), 436-447.

Xin Y. P., Tzur, R., & Si, L. (2008). Nurturing Multiplicative Reasoning in Students with Learning Disabilities in a Computerized Conceptual-Modeling Environment. National Science Foundation (NSF) funded project.

Yin, K. (2014). *Case study research: Design and methods* (5th ed.). Thousand Oasks, CA: Sage.