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Claire Wladis, Kathleen Offenholley, Jae Ki Lee, Dale Dawes, Susan Licwinko

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An instructor-generated concept framework for elementary algebra in the tertiary context

Claire Wladis^{1,2}, Kathleen Offenholley^{1,3}, Jae Ki Lee^{1,4}, Dale Dawes^{1,5}, Susan Licwinko^{1,6}

¹Borough of Manhattan Community College at the City University of New York, Mathematics Department, New York, USA

²Graduate Center at the City University of New York, Urban Education Department, New York, USA

cwladis@bmcc.cuny.edu

³koffenholley@bmcc.cuny.edu

⁴jk12105@tc.columbia.edu

⁵ddawes@bmcc.cuny.edu

⁶slicwinko@bmcc.cuny.edu

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Elementary algebra and other developmental courses have consistently been shown to be barriers to student degree progress and completion in the United States. Significant research has been done in the primary and secondary context, but little research has been conducted with students enrolled in elementary algebra courses in the tertiary context, despite the fact that there is significant evidence to suggest that mathematics learning is likely somewhat different in this context (Mesa, Wladis, & Watkins, 2014).

Teacher beliefs and expertise

There is significant research suggesting that teacher beliefs are often strongly related to the teaching practices that teachers implement in the classroom, and therefore are also related to student beliefs and learning experiences (see e.g. Fang, 1996; Maggioni & Parkinson, 2008). In addition, teacher expertise also has the potential to benefit the research community by contributing important information about what teachers have learned while teaching.

Theoretical framework

This study uses Vygotsky's (1986) theory of concept formation: learners begin to use algebraic symbols, graphs and other representations before they have "full" understanding of them, and through this experimentation and communication with "more knowledgeable" others, they internalize more formal and correct meanings for the objects that the representations symbolize.

Methodology and results

Five elementary algebra instructors collaborated on this action research project, some of whom are also educational researchers. This included faculty with doctorates in both mathematics and mathematics education, with varied backgrounds and different teaching styles. This study used the *Action Research Spiral* Framework (Kemmis & Wilkinson, 1998) to guide the process of collaborative exploration into student thinking about elementary algebra concepts. This framework outlines a cyclical practice in which practitioners go through the following steps repeatedly: 1) plan; 2) act and observe; 3) reflect; 4) revised plan, etc... In a cyclical process of experimentation, instructors developed assignments and assessment questions intended to assess student

understandings on the framework (see Table 1) that they had initially developed through discussion based on prior teaching experience. An example of one type of assessment question is below:

- Assume that $a \neq 0$. Dale simplifies the expression a^3a^{-2} and gets the correct expression a . Which of the following must be true? There may be **more than one** correct answer—select **ALL** that are true.
- $a^3a^{-2} = a$
 - If Dale lets $a = 10$ in both the expressions a^3a^{-2} and a , he will get two different answers.
 - Dale can substitute a for a^3a^{-2} anywhere it appears in an algebraic expression.
 - If Dale lets $a = 20$ in both expressions, he will get the same value for each expression.
 - Dale needs to know the value of a before he can say whether a^3a^{-2} and a are equal.

This question was designed to test the extent to which students understand 4.a. in the framework. Based on student responses, instructors probed students about their understanding of specific components of item 4.a. in order to better understand what those are and how they relate to one another. Based on this process, the framework was revised: The first draft contained only item 4.a.ii.1; after repeated cycles the other items under 4.a. were added and structured hierarchically.

1. Algebraic Symbolism
2. Algebraic Structure
3. Properties/Generalizing Arithmetic Operations
4. Equality/Equivalence: Understands equality/equivalence. The student understands: <ol style="list-style-type: none"> what it means for two expressions to be equal <ol style="list-style-type: none"> that two expressions are equal iff they are equal for all possible variable values that if two expressions are equal, one may be substituted for the other in any context <ol style="list-style-type: none"> that rewriting expressions is a process where an expression is replaced by an equivalent one what it means for two equations to be equivalent
5. Equations as Relationships between Variables
6. Thinking Graphically
<i>Note: Because of space constraints, not all details of the framework could be reported here</i>

Table 1. Elementary Algebra Concept Framework, with details for one sample sub-concept

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