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Lynne Gannon Patterson
Murray State University

Meagan Musselman
Murray State University

Joel Rowlett
Smyrna High School in Smyrna, Tennessee

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Lynne Gannon Patterson, Murray State University
Meagan Musselman, Murray State University
Joel Rowlett, Smyrna High School in Smyrna, Tennessee

Abstract

This study examined the midterm exams of six high school math teachers and sought to (a) determine if teachers could accurately identify which level of Norman Webb's Depth of Knowledge (DOK) model their test items aligned to, and (b) compare the actual percentage of test items at each DOK level to the targeted percentage based off Webb's research. The study revealed that teachers were not accurate with their alignment of test items with Webb's DOK model. They also came up short in comparison to the targeted percentages of test items at each level. Comprehensively, they were asking more questions at Level 1 and 2 instead of at Level 3 or 4. Recommendations are provided on how teachers can write questions at the targeted level for their course. Advancing high school students' depth of knowledge (DOK) in mathematics can be challenging, so it is important for assessments to meet the appropriate levels of DOK. Finally, assessing the DOK levels of created test items is a task that can be difficult for most high school teachers. These challenges were the backdrop of this study.

Keywords: depth of knowledge, high school, mathematics, assessments

Purpose

The purpose of this study is to uncover whether teachers know how to use the Depth of Knowledge (DOK) scale to construct high school mathematics assessments. After in-service training on Depth of Knowledge, teachers constructed tests for their midterm exams using the DOK scale. An item analysis of the exams and a teacher survey were used to determine whether the teachers were implementing research through practice and specifically utilizing the DOK scale as they constructed student assessments.

Background

According to Norman Webb, a Wisconsin Center for Education Research senior scientist, effective schooling depends on coordinating three components of the educational environment: curriculum, instruction, and assessment. The degree to which these elements work together toward student learning is termed *alignment* and provides the foundation of standards-based educational reform (Wisconsin Center for Education Research, 2006). Webb developed a process and criteria for systematically analyzing alignment, known as the Depth of Knowledge Model. The model assumes that curricular elements can be categorized based on the cognitive demands required to produce acceptable responses. Each grouping of tasks reflects a different level of cognitive expectation, or depth of knowledge, required to complete the tasks (Tennessee Department of Education, 2013). Webb's DOK Model illustrates the detailed DOK model, including descriptors and expectations of each level. Webb has developed a systematic procedure for determining the degree to which curricular "expectations and assessments are in agreement" (Popham, 2008, p. 22). The categories created by Webb are:

- Level 1: Recall and Reproduction
- Level 2: Skills and Concept
- Level 3: Strategic Thinking
- Level 4: Extended

Literature Review

In today's high school classrooms, we understand the importance of purposeful

and meaningful assessment. As Carol Ann Tomlinson has stated, "Informative assessment is not an end in itself, but the beginning of better instruction" (Tomlinson, 2008, p. 13). Testing students with the DOK Conceptual Model in mind can be a determining factor in future progress.

Too few students – including those who excel academically – regularly have education experiences that stimulate and stretch them. *Teaching up* is one key approach that teachers can use to regularly make such experiences available to all students, regardless of their background or starting points (Tomlinson, 2012, p. 29). Carol Ann Tomlinson along with Edwin Lou Javius provide seven key principles of *teaching up* including: accepting that human differences are not only normal but also desirable; developing a growth mindset; working to understand students' cultures, interests, needs, and perspectives; creating a base of rigorous learning opportunities; understanding that students come to the classroom with varied points of entry into a curriculum and move through it at different rates; creating flexible classroom routines and procedures that attend to learners' needs; and being an analytical practitioner (Tomlinson, 2012, p. 31-32).

Understanding and utilizing DOK in assessment regularly can strengthen the "growth mindset" of our students and impact their tomorrows. Carol Dweck and her colleagues identified two distinct ways in which individuals view intelligence and learning. Individuals with a *fixed mindset* believe their intelligence is simply an inborn trait – they have a certain amount, and that's that. In contrast, individuals with a *growth mindset* believe that they can develop their intelligence over time (Dweck, 2010, p. 16). Building and developing the growth mindset in our students through targeting higher levels of DOK will strengthen our students' lifelong problem-solving skills.

Upon examination of the DOK Conceptual Model, one can see the progression through the four levels. For example, Level 1 may require a student to only recall or define a term, while Level 2 may require a student to predict or compare; Level 3 may ask a student to revise or assess, and finally Level 4 may require a student to critique or design another solution (Tennessee Career & Technical Education, 2010-2011, p. 22).

Furthermore, the Kentucky Department of Education (2007) provides representative examples of DOK activities for each level. Some examples that represent but do not constitute all Level 1 DOK performances in mathematics are:

- Identify a diagonal in a geometric figure.
- Multiply two numbers.
- Find the area of a rectangle.
- Convert scientific notation to decimal form.
- Measure an angle.

Some examples that represent but do not constitute all Level 2 DOK performances in mathematics are:

- Classify quadrilaterals.
- Compare two sets of data using the mean, median, and mode of each set.
- Determine a strategy to estimate the number of jellybeans in a jar.
- Extend a geometric pattern.
- Organize a set of data and construct an appropriate display.

Some examples that represent but do not constitute all Level 3 DOK performances in mathematics are:

- Write a mathematical rule for a non-routine pattern.
- Explain how changes in the dimensions affect the area and perimeter/circumference of geometric figures.

- Determine the equations, and solve and interpret a system of equations for a given problem.
- Provide a mathematical justification when a situation has more than one possible outcome.
- Interpret information from a series of data displays.

Some examples that represent but do not constitute all of Level 4 DOK performances in mathematics are:

- Collect data over time, taking into consideration a number of variables and analyzing the results.
- Model a social studies situation with many alternatives and select one approach to solve with a mathematical model.
- Develop a rule for a complex pattern and find a phenomenon that exhibits that behavior.
- Complete a unit of formal geometric constructions, such as nine-point circles or the Euler line.

Additionally, DOK goes hand-in-hand with Common Core Standards for Mathematical Practice. Through purposefully assessing students' depth of knowledge, math teachers are incorporating the Common Core Standards into their teaching and assessments for learning. According to the 2012 Kappan poll, most Americans believe the Common Core Standards will allow U.S. schools to compete globally, and three of four Americans believe the Common Core Standards will provide more consistency in the quality of education between school districts and states (Bushaw, 2012, p. 11).

All four levels of DOK also support the following Standards for Mathematical Practice (National Governors Association Center for Best Practices, 2010):

- Make sense of problems and persevere in solving them.
- Reason abstractly and quantitatively.
- Construct viable arguments and critique the reasoning of others.
- Model with mathematics.
- Use appropriate tools strategically.
- Attend to precision.
- Look for and make use of structure.
- Look for and express regularity in repeated reasoning.

Research has shown that students should be given the opportunity to explore mathematics concepts by building on their knowledge and focusing on mathematical reasoning….Certain teaching practices can support students' mathematical reasoning (Akyuz, 2012, p. 332). Today's high school students not only need to have opportunities to reason in mathematics, but be assessed on that reasoning through DOK-based assessment strategies, as well.

In high school, students should build on their prior knowledge, while learning more varied and more sophisticated problem-solving techniques (National Council of Teachers of Mathematics [NCTM], 2000, p. 288). Through assessing depth of knowledge while keeping the Common Core Standards for Mathematical Practice at the forefront of high school mathematics programs, high school teachers can better prepare students for career, college, and life in the future. Both creativity and critical thinking have been flagged as essential 21st century skills, yet some people think of them as being as separate as oil and water. Sir Ken Robinson, an internationally recognized leader in the development of creativity, innovation, and human resources, states that everybody has tremendous creative capacities. A policy for creativity in education needs to be about everybody, not just a few (Azzam, 2009, pp. 22-23). Depth of Knowledge assessment is for all learners.

Methods

A total of six teachers were selected from a midsize southern high school's math department to participate in this study. The assistant principal described each participant and summarized the interview questions as follows in order to describe the teachers:

Teacher A has a bachelor's degree in pastoral studies and a master's in divinity. He is in his fifth year of teaching. Teacher A never answered whether he was familiar with Webb's DOK scale. He did report, however, that state testing prompts him to include higher-order thinking questions on all assessments. He readily admits that, although every year he tries to assess his students at higher levels, he could do more to create more balanced assessments. While reflecting on his assessment formats, he agreed that he probably assesses at Level 1 too often. As a result, he constantly reminds himself to include higher level questions. "I wish it came naturally," he said, "but it doesn't." As a result, Teacher A regularly reviews and revises his assessments.

Teacher B has a bachelor's degree in mathematics and is currently pursuing a master's degree in advanced studies in teaching and learning. She has 15 years of teaching experience. Although she states that she is familiar with Webb's DOK scale, she admits that she never uses Level 4 problems on her assessments. She reports that her questions are focused on "skills and concepts with some Level 3 mixed in." She prefers to restrict Level 4 questions for extended thinking exercises during class work and homework. Her midterm consisted of 50 multiple choice items for an Honors Algebra II class.

Teacher C has a bachelor's degree in psychology, a bachelor's degree in applied cultural anthropology, and a master of education degree. She has 15 years of teaching experience. Although she is familiar with Webb's DOK scale, she uses Bloom's Taxonomy to create a broad range of assessment questions. Since she teaches special education, she intentionally assesses her students at Levels 1 and 2 to prepare them for the state's end-of-course assessment. She does, however, implement higher-order thinking opportunities for her students through labs and project-based assignments to "intrigue the students." Teacher C states that her assessment questions are not balanced because her "students' disabilities inhibit algebraic learning." For her students, she tries to teach algebra in a manner similar to that used to teach a foreign language – repetitive drilling of basic skills. Her midterm consisted of 7 free response items, 5 matching items, and 30 multiple choice items.

Teacher D has a bachelor's degree in special education. She has 14 years of teaching experience. She states that she is not familiar with Webb's DOK scale and believes that her assessments are not balanced among the four question levels. Her midterm exam consisted of 30 multiple choice items for a resource geometry class.

Teacher E has a bachelor's degree in mathematics and is currently in his first year of teaching. Although familiar with Webb's DOK scale, he uses it "somewhat," trying to include at least "a couple of questions from the four levels" on all assessments. He believes that his assessments are balanced among the four level types but would like to include more Level 3 and Level 4 questions. His midterm exam consisted of 50 multiple choice items for a standard geometry class.

Teacher F has a bachelor's degree in mathematics and over 40 years of teaching experience. Although she is familiar with Webb's DOK scale, she does not reference it when structuring assessment questions. She does try to be mindful of the need to include a mix of all question types and believes that her questions are "well-balanced." When

questioning students, she tries to start with basic recall questions and progresses to multi-step and analysis problems. Her midterm consisted of 55 multiple choice items, 2 geometric constructions, and 2 proofs.

Procedures

This study sought to answer the following research questions:

- How do teachers know that the test items they create assess the appropriate levels of DOK?
- How can teachers write questions to assess their students' mathematical abilities at all four levels?
- Can a teacher create a test item and accurately identify the level of DOK for that test item?
- Is there a difference between DOK questions used in different levels of high school math courses?

To answer these questions, the authors examined the midterm assessments of six high school teachers previously described. The six teachers included one geometry teacher, one advanced honors geometry teacher, one special education geometry teacher, one Algebra I teacher, one special education Algebra I teacher, and one advanced honors Algebra II teacher. These teachers assigned their own perceived DOK levels to the questions on their midterm exams. As outside evaluators, we assigned DOK levels to the questions on the midterm exams according to the descriptions from Webb's Targeted Distribution (Kentucky Department of Education, 2007). We then compared the teachers' perceived DOK levels with their actual DOK levels and compared their actual DOK levels to the targeted DOK levels.

According to Webb, we should see a trend in values. We would expect more DOK 1 and 2 questions in the more basic skills classes, progressing to more DOK 3 and 4 questions in the advanced skills classes. However, our findings revealed that not only did the teachers' actual assessment questions come up short in regards to DOK, but their predicted values did as well. This implies that the teachers did not even think they were asking the more advanced questions like they should be. For example, in geometry, almost 42% of questions should be at DOK 4 (Kentucky Department of Education, 2007). In our study, the geometry teacher only predicted she had 4% at this level, but in fact did not have any.

According to Webb, the levels for high school mathematics should look like what is shown in Table 1 in order to provide flow for the curriculum.

Discussion

As teachers create their assessments for learning and utilize depth of knowledge, it is important that they ensure that mathematics curriculum flows well across coursework. However, our findings indicate that teachers' actual DOK levels of assessment and the targeted DOK levels proposed by Webb's model are disconnected. Additionally, teachers' perceived levels of DOK and their actual levels of DOK are disconnected. This situation makes for an interesting problem in need of a solution if we want to positively impact the focus and cognitive level of educational experience for students across all grades and courses.

Figure 1 shows Webb's targeted distribution for a high school Algebra I class. According to Webb, a progression should occur as students proceed through the grades and into high school content areas. This progression shows that students in Algebra I should ideally experience their math content and assessments at the following levels: 8.70% at Level 1 DOK, 13.04% at Level 2 DOK, 47.83% at Level 3 DOK, and 30.43% at Level 4 DOK. In the

actual distribution of the teachers in our study, we found that the Algebra I teacher assessed students at 51% DOK for Level 1 and 47% for Level 2. The teacher's assessment did not include Level 3 or Level 4 questions. Figure 1 shows this graphically.

Figure 2 shows Webb's targeted distribution for a high school geometry class. Students in high school geometry should ideally experience their math content and assessments at the following levels: 00.00% at Level 1 DOK, 12.50% at Level 2 DOK, 45.83% at Level 3 DOK, and 41.67% at Level 4 DOK. In the actual distribution of the teachers in our study, we found that the geometry teacher assessed students at 18% for Level 1, 74% for Level 2, and 4% for Level 3. The teacher's assessment did not include any items for Level 4.

Figure 3 shows Webb's targeted distribution for a high school Algebra II class. Students in Algebra II should ideally experience their math content and assessments at the following levels: 00.00% at Level 1 DOK, 11.54% at Level 2 DOK, 34.62% at Level 3 DOK, and 53.85% at Level 4 DOK. In the actual distribution of the teachers in our study, we found that the Algebra II teacher assessed students at 14% for Level 1, 82% for Level 2, and 6% for Level 3. The teacher's assessment did not include any items for Level 4.

Recommendations

This study shows a strong disconnect between teachers' beliefs and practices. The teachers' actual DOK levels and targeted DOK levels are disconnected. As a result, their assessments fail to include an adequate sample of Level 3 and Level 4 questions.

So how do you advance your students' depth of knowledge through assessment? The following are our suggestions in response to our introductory questions:

- Question 1: How do teachers know that the test items they create assess the appropriate levels of DOK?
  - Analyze the test items in your professional learning community team meetings. Exchange tests and analyze your team members' tests.
  - As a team, analyze test items before you administer the assessment to students.
  - As a team, analyze test items after you administer the assessment to students.
  - Reflect and discuss your decisions and student responses.
  - Include your administrators in your discussions of test items.
  - Know that you do not have to work in isolation.
  - Focus on building a growth mindset in your students to reach higher levels of DOK in your assessments.
- Question 2: How can teachers write questions to assess their students' mathematical abilities at appropriate levels?
  - Use the Depth of Knowledge Model and examples when creating tests.
  - Work in steps to move toward optimizing depth of knowledge.
  - Work in collaborative teams to optimize results and create the best questions for your students.
  - Reflect back upon student responses. Examine responses for patterns. Ask students to explain their thinking about incorrect responses.
  - Finally, take the assessment yourself and reflect upon what your students are experiencing.
- Question 3: Can a teacher create a test item and accurately identify the level of DOK for that test item?

- With practice and through discussions with other teachers, teachers can learn to create an appropriate test item at the appropriate level of DOK.
- Keep in mind that this is formative assessment in action. This also transforms into better instructional practices for you and your students.
- Continually assess test items before, during, and after teaching and assessing.

- Question 4: Is there a difference between DOK questions used in different levels of high school math courses?
  - Allow DOK to help you vertically align your whole math instruction program.
  - Realize that all students can experience DOK learning and assessment regardless of the level of the course.
  - Provide educational experiences for all students that can stimulate and stretch their thinking and problem-solving abilities.
  - Encourage creativity through assessment as all levels.
  - Plan and review your instruction leading up to the assessment for DOK levels.

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Lynn Gannon Patterson is Assistant Professor, Murray State University.
Meagan Musselman is Assistant Professor, Murray State University.
Joel Rowlett is Principal, Smyrna High School in Smyrna, Tennessee.