Existing Mathematics Teaching Practices at an HBCU: Foundations for Teacher Preparation

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The Mathematics Teacher Education Partnership (MTE-P) seeks to transform the preparation of secondary mathematics teachers through several avenues of research and development. One of those avenues is being pursued by a research community supported by MTE-P that is known as the Active Learning Mathematics Research Action Cluster (ALM-RAC). Active learning involves a student-centered pedagogy in which students are encouraged to reason about thought-provoking problems (Smith, 2015). The goal is to raise student thinking to higher levels of Bloom's taxonomy (Krathwohl, 2002) in settings that encourage them to discuss mathematics with each other and to communicate about and defend their mathematical thinking—to be "active" mentally and socially in the lesson and in the classroom learning community rather than to be passively listening to a lecture (Diederich, 2010; Smith, 2015).

Higher-level of thinking is thinking that happens in the analysis, synthesis, and evaluation of a topic (Teach For America, 2011). Why do we want students engage in higher-level thinking? We would like students to remember mathematical ideas longer and more clearly. If students engage in higher-level thinking, they can have an increased ability to retain and apply mathematical knowledge (Garrett, 2014; NCTM, 2009). Consider the difference between memorizing multiplication tables and the deeper understanding that comes from connecting those operations to different ways of thinking such as an area model (NCTM, 2000). Such connections build a web of understanding that helps students access and use knowledge (Van de Walle, Karp, & Bay Williams, 2015).

The qualities of assessments used in mathematics courses are connected to the type of learning students will experience as well as the type of instruction. In the traditional lecture, students typically select an answer or recall information to complete an assessment. An assessment aligned with higher-level thinking is essential if students are expected to engage in such thinking in different classroom and assignment tasks. An instructor can identify the task that needs to be mastered and then a curriculum can be developed that will enable students to perform those tasks well (McDonald, 1992).

Theoretical Foundation: The Exam Characterization Framework

The *Exam Characterization Framework* (ECF) was developed as part of the Mathematical Association of America's efforts to provide empirical evidence for best practices in college mathematics instruction (Tallman, Carlson, Bressoud, & Pearson, 2016). In their efforts to characterize the nature of college Calculus 1 final exams, Tallman et al. formulated their own evaluation framework, the ECF, following an extensive review of existing frameworks and associated literature. They constructed their framework through "12 cycles of . . . coding exam items [on 5 Calculus I final exams,] refining [the] characterization of ECF constructs and recoding items" (p. 4).

The Framework. This developmental work resulted in three "item attributes" that are used to describe the qualities of exam items and thereby describe the qualities of the exam (Tallman et al., 2016, p. 7). *Item orientation* refers to the type of thinking that is needed for each exam item. *Item representation* refers to the type of representations present in the statement of the problem as well as the type of representations needed to solve the problem. *Item format* refers to whether or not the item is multiple choice, short answer, or a broad open-ended problem and whether or not the item requires an explanation.

Item orientation was broken down into seven levels. In their study, Tallman et al. (2016) found that only the first five levels were present in the Calculus 1 final exams they examined. They provided exam item examples in their report for each of the first five levels to facilitate the use of the framework by those wishing to characterize the level of cognitive demand present in examinations. Those first five levels, *remember, recall and apply procedure, understand, apply understanding,* and *analyze* are described in Table 1 and examples given of some of the behaviors that will be expected of students from those types of exam items. Level six, not found in the exams Tallman et al., looked at, was *evaluate,* which involves "mak[ing] judgments . . . checking and critiquing" (p. 9). Level seven, also not found, was *create,* which involves assembling, producing, generating and planning using mathematical ideas in ways that create new patterns. Levels five, six, and seven were informed by Krathwohl's (2002) discussion of Bloom's Taxonomy.

Their Study. Once they had a useful framework, Tallman et al. (2016) examined a sample of 150 Calculus final exams randomly drawn from 253 used during the 2010-2011 academic year at 253 different universities. The sample of 150 was comprised of about 62% from national universities, 23% from regional universities, 9% from community colleges, 5% from national liberal arts colleges, and 1% regional colleges. The selected exams were coded with the ECF until the results stabilized, which occurred after about 100 exams. Analysis showed that the Calculus 1 final exams had low levels of cognitive demand and did not address the key ideas of the course in a way that allowed students to show understanding. Of the 3735 individual exam items they coded, about 85% were at the two lowest levels of exam orientation, remembering or recall and applying procedures.

Table 1
Levels of Item Orientation (Tallman, et al., 2016)

Level	Description	Example behavior
Remember	The only requirement is the retrieval of information, not the use or understanding of it.	Stating a theorem
Recall and apply procedure	When students are asked to use a particular procedure, they can remember the procedure and use it. They need not understand why it works or under what conditions.	Use a named formula to solve a given problem.
Understand	Students must provide explanations, demonstrate their reasoning, or in other ways show that they understand.	Interpreting the meaning of a mathematical construct as applied to a real-world context.
Apply understanding	Students are not provided with information as to what formula or theorem to apply. They must decide based upon understanding.	A real-life application problem that makes clear the situation and needed result without stating anything about the techniques to use to solve the problem.
Analyze	Students must break down complex ideas and "explain how complex ideas are connected" (p. 11).	An essay in which students describe how one mathematical concept is connected to others.

Connections. This report provides information that will help institutions to evaluate the assessments they are using in their college courses and raise the cognitive level of the summative assessments used. It is our belief that teaching aligned with such assessments will encourage an active learning pedagogy in the college mathematics classroom. It is our expectation that future secondary mathematics teachers and others who take such courses will learn to think critically, to see how teaching for higher level thinking looks, and will be better equipped to help their any students they may have engage in higher level thinking.

Results

As part of an effort to collect baseline data regarding current practices, we asked faculty members in a mathematics department at a Historically Black University in the Southern United States to provide samples of the exams they used in Precalculus and Calculus. We wanted to know the level of the cognitive demand of the exam items used in these courses. Eight faculty members responded and provided 15 exams: 3 final exams, 6 Precalculus unit exams and 6 Calculus unit exams. Of the 6 Calculus exams provided, two were removed from our analysis so that any individual faculty member would not have provided more than 2 exams to the sample. An individual coder, using the first five levels of the Item Orientation framework of the ECF, coded the 6 Precalculus unit exams and the 4 Calculus unit exams. The examples provided by Tallman et al. (2016) were compared with items on the sample exams, as were verbal definitions of the item orientation levels. This analysis provided a snapshot of the level of cognitive demand of Pre-Calculus and Calculus unit exams at one HBCU.

Precalculus. A total of 102 items on 6 Precalculus exams were coded. Of those items, 3 were coded as remembering, 95 were coded as recall and apply procedure, 1 was coded as understanding, 2 were coded as apply understanding and 1 was coded as analyze. Figure 1 shows the percentages of Precalculus exam items in each level of orientation. Note that 96% of the items were at low levels of cognitive demand.

Calculus. A total of 82 items on 4 Calculus 1 exams were coded. Of those items, none were coded as remembering, 73 were coded as recall and apply procedure, 3 were coded as understanding, 6 were coded as apply understanding, and none were coded as analyzing. Figure 1 shows the percentages of Calculus exam items at each level of orientation.

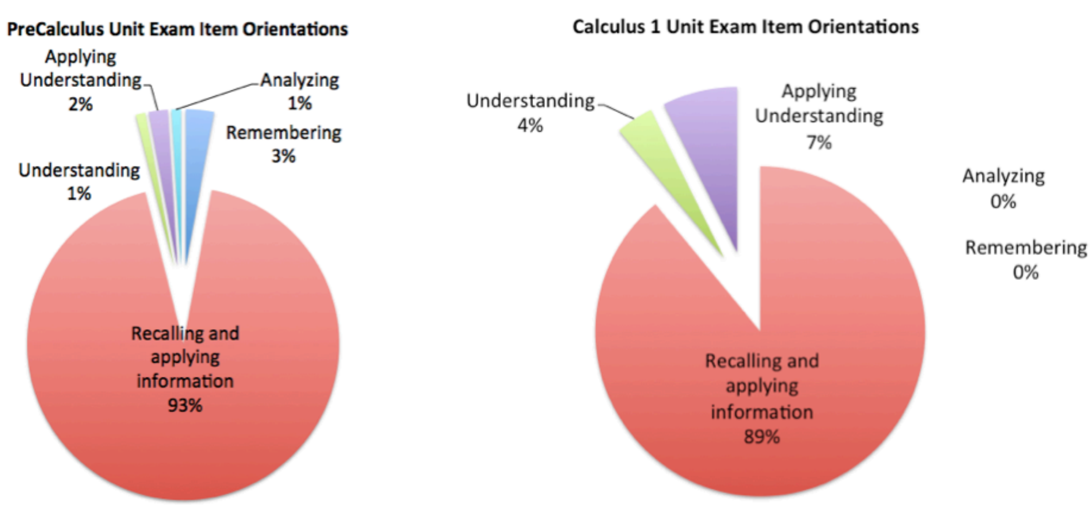

Figure 1: Levels of item orientation seen on 6 Precalculus exams (left) and 4 Calculus exams (right) provided by HBCU faculty.

Note that the percentage of higher level orientation (HLO) for the Calculus exams is better than for the Precalculus exams (11% HLO Calculus vs. 4% HLO Precalculus), but still lower than the national average for Calculus final exams (15% HLO).

Conclusion

The level of item orientation for those faculty members who submitted exams was higher for Calculus by 7% than it was for Precalculus. Precalculus students were rarely expected to think above the levels of remembering or recalling and applying procedures. Although Precalculus may be seen primarily as a precursor to Calculus and preparatory of the algebraic skills Calculus students will need, there needs to be more to the course than building algebraic proficiency. Any higher-level thinking asked of students in Precalculus will help build their ability to connect mathematical ideas, retain those ideas and engage in higher-level thinking skills in other areas of study. This is particularly important if instructors wish to produce critical thinkers that will be able to contribute to beneficial innovations in their professional fields (Tyler & Cruz, 2016; Wagner, 2011).

Talking and listening, one of the four basic elements of Active Learning, will change the passive learning from our students by having more participation in the lecture, and interaction with their classmates. These will improve the level of thinking, our next steps include increasing awareness in the mathematics department of the levels of thinking currently being expected of our students, encouraging implementations that seek to raise the level of thinking expected, and conducting research that provides evidence as to the effect of those implementations. Once change has begun in the mathematics department, it is expected that recruitment work can be more effective as we seek to increase the number of students at our institution majoring in secondary mathematics education. Tracking institutional change at the university of this study can also provide evidence for those seeking to encourage change at their institutions.

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