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College of Education Graduates: What Mathematics Do They Know?

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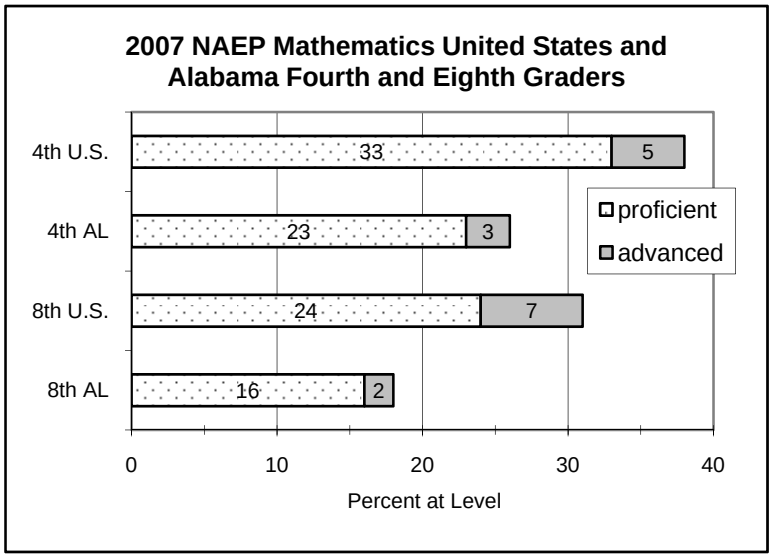
Abstract

Beginning with 2008 graduates, the state department of education of Alabama, required that all college of education students meet an established level of proficiency on six pre-algebra mathematics standards in order to receive certification. Because college of education students do not take any common Arts and Sciences mathematics courses, an independent math assessment was developed within the college of education. Online computer modules for review and assessment were created. In 2008, approximately 300 elementary and secondary education students in a southeastern U.S. public university were assessed. Additionally, students completed a questionnaire, as part of the test registration, which asked for student major and mathematics courses taken in college. An analysis of the data collected from the assessment indicates that the elementary majors outperformed the secondary majors with the exception of the secondary mathematics students.

For many years, Alabama has consistently remained among the states whose students score the lowest on national mathematics achievement tests such as the National Assessment of Educational Progress. (See figure below.) One unfortunate outcome of this lack of content knowledge is the cyclical nature of remediating college students and graduating teachers with weak mathematics content knowledge who then become Alabama teachers unable to effectively or substantially increase their students' mathematics content knowledge. The content knowledge of the teacher has been linked to student achievement (Hill, 2007). The purpose of this paper is to report on an assessment of the mathematics content knowledge of a population of pre-service teachers, and report on a model being designed for addressing the *remediation* of identified subsets of this college student population.



In 2008, the National Mathematics Advisory Panel was commissioned by the U.S. Department of Education to consolidate and evaluate research on mathematics learning and teaching to produce a set of recommendations to take action for improvement. The panel described the mathematics education system as being broken and that it must be fixed. Furthermore, not only is a strong education in mathematics a national interest, success in mathematics is important for empowering and enabling individual citizens. The panel acknowledged that a central role in mathematics education is a mathematically knowledgeable classroom teacher.

The Final Report of the National Mathematics Advisory Panel (2008) produced a set of recommendations for the direction of mathematics education and research. In particular, the report recommends that the mathematical preparation of elementary and middle school teachers must be strengthened as one means for improving teachers' effectiveness in the classroom.

Alabama Teacher Certification Content Standards

Colleges and universities with teacher education programs ensure their graduates will be awarded state certification to teach by meeting the standards of their respective state departments of education. Standards are revised periodically to reflect the needs of the population being served. In the spring of 2007, the State Board of Education in Alabama approved the Alabama Quality Teaching Standards (AQTS) and required teacher training institutions to begin implementing the standards in fall of 2007. The AQTS include standards of mathematical literacy for all teacher candidates, not just teachers of mathematics. The six indicators of mathematics literacy are the following:

1. Knowledge of the role that mathematics plays in everyday life
2. Knowledge of the concepts and relationships in number systems

3. Knowledge of the appropriate use of various types reasoning, including inductive, deductive, spatial, and proportional, and understanding valid and invalid forms of reasoning
4. Knowledge of both metric and customary measurement and fundamental geometric concepts including shapes and their properties and relationships
5. Ability to solve problems using different strategies, to verify and interpret results, and to draw conclusions
6. Ability to communicate with others about mathematical concepts, processes, and symbols

There was no indication that requiring pre-service teachers to demonstrate competency on these mathematics indicators would be difficult given the level of mathematics of the indicators. Five of the six indicators are listed on the Alabama K-12 mathematics course of study as elementary level (by the sixth grade) and are building blocks for high school mathematics courses. The remaining indicator of number systems and definitions is traditionally discussed in algebra class or when students are introduced to irrational numbers and the Pythagorean Theorem in middle grades. College students who were assessed on the indicators had completed their mathematics content college level classes.

Verifying Competency on Standards?

At the University of South Alabama state mandated teacher certification standards are assigned to university courses and linked to electronic student portfolios. At the end of the term, course instructors submit a score for each standard assigned to their course based on course assignments or documents uploaded by students. The dilemma created by the required mathematics standards was students not having a common course in which the standards had a match with content. Furthermore, there is no common mathematics course required for all education majors. A decision was made to create an online "course" which contained the mathematics component of the standards and students would be enrolled in this course which carried no credit and no additional fees. Study guides for the mathematics content were posted on this course as well as a description of the standards and references for further information. Students were contacted via email and targeted instructors to explain the procedures for mastering the standards and for the assessment.

Indicators Assessment

The assessment consisted of 5 quizzes each with 10 multiple choice questions for indicators 1 through 5 and one written response on indicator 6. Six correct responses from the 10 questions were required for basic competency on each indicator, and 8 correct responses would determine proficiency. Students had the opportunity to retake similar quizzes if needed to master the indicator, or indicate proficiency.

Data Analysis

Population

The population from spring and summer semesters in 2008 consisted of 210 students, with 79% female, 73% White, 18% Black, 50% under age 24, and 22% over age 30. The large number of female students could be attributed to the large numbers of early childhood and elementary majors (60%). Of the secondary education majors, just over half were majoring in physical education or health and greater than one- fourth were social studies majors.
While nearly three-fourths of the students reported having taken 3 or more college level mathematics courses, within the last 1-2 years, less than 15% reported taking calculus or higher level mathematics.

Results

Between 50 and 52 percent of the students were able to score the minimum, 6 correct on indicators 1(math in everyday life), 3 (types of reasoning), and 6 (communicate). Greater than 60% of the students scored at basic competency on indicator 4 (measurement and geometry). Approximately 40 percent scored basic on indicator 5 (solving problems with different strategies) and less that 20 percent on indicator 2 (number systems). An average score was calculated for each indicator using the points earned divided by attempted points. Average scores ranged from a low of 53 percent for indicator 2 (number systems) to a high of 71 percent for indicator 4 (geometry and measurement).

Using one-way analysis of variance (ANOVA), the number of times students attempted indicator 4 (measurement and geometry) and indicator 5 (using different strategies) differed significantly ($p<0.01$) between elementary and secondary majors. Significance was also indicated for the mean scores on indicator 5 between elementary and secondary students. Removing the secondary mathematics majors (n=4) from the data, the second indicator (number systems) was significantly different for both the number of attempts and the mean scores between elementary and secondary students.

Sample Questions and Response Rates

Indicator One

Smalltown is divided by Main Street into a west side and an east side. On the west side of town, 20% of the children qualify to receive free or reduced lunch at school. On the east side of town, 30% of the children qualify. Which of the following statements is true?

A. In Smalltown, 20% of the children qualify for free or reduced lunch.
B. In Smalltown, 25% of the children qualify for free or reduced lunch.
C. In Smalltown, 50% of the children qualify for free or reduced lunch.
D. There is not enough information to calculate how many children in Smalltown qualify for free or reduced lunch.

Only 5 percent of the students answering this question selected the correct response, while 87 percent selected response C.

> Your credit card charges you 20% interest annually on remaining balances and you now have a balance of $100. If you pay nothing on your credit card, and there are no other penalty charges, at the end of two years how much would you owe to this credit card company?
>
> A. $120
> B. $140
> C. $144
> D. More than $145
> E. None of these

More than half of the students selected B, and only 13 percent selected the correct response, C.

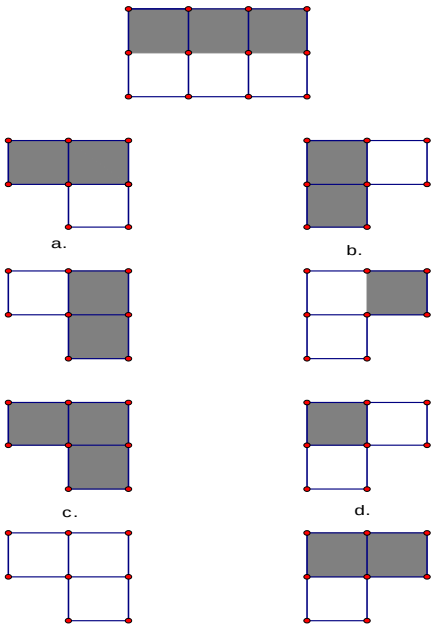
Number systems (indicator 2)

Questions required students to differentiate between rational, irrational, integers, and whole numbers. The mean for indicator two was 4.42 (of 10) points, median 4 and mode 3. This indicator was the most difficult for students to achieve competency with two areas being the least likely to illicit a correct response: irrational number property recognition, and selecting the correct Venn diagram of the real number systems. Of those assessed, only 14% of the students were able to select the correct Venn diagram.

Logic and Reasoning (Indicator 3)

Graph reading was strong, except when it was necessary to translate percent to fraction. Logic arguments and questions of proportional reasoning did not result in many errors. Approximately half the students had difficulty with conditional statements resulting in valid and invalid arguments, and half the students had difficulty with spatial reasoning. The following question is an example of the question used for spatial reasoning.

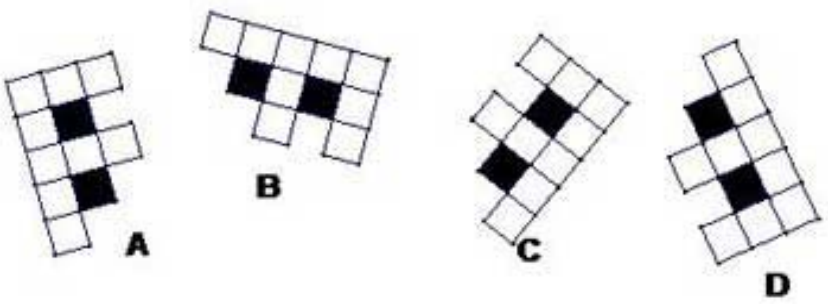
> Which pair of tiles below, when joined, will make the top pattern of six squares?



Correct choice b was selected by 57 percent of those assessed.

Less than half the students who received the following question selected the correct response.

Which of the following patterns does not match the others?



Geometry and Measurement (Indicator 4)

Geometry and measurement appeared to be the least difficult for students and therefore had the highest average and pass rate for all students. There was some difficulty with knowing geometry terms and concepts: quadrilateral, similar, and congruence. Students did not generally know the definitions of geometric terms well enough to understand the finer distinctions such as the fact that all squares are rectangles.

Strategies, interpreting results, and drawing conclusions (Indicator 5)

An example of a problem in this category would be for students to decide whether or not a selected procedure was valid and could be used in similar circumstances, or whether the correct answer was obtained, but the procedure is not valid. For example, understanding that repeated

subtraction could be used for a problem where division is required. Again in this category, elementary majors outperformed secondary majors. The following question was included on most of the quizzes for indicator 5.

Sue was asked to **divide** 8 by ¼. Sue said, "One fourth of 8 is 2, so the answer is 2."

A. Sue does not have a good understanding of division by fractions.
B. Sue seems to have a good concept of division by fractions.
C. Sue's answer is correct, but there is not enough information to tell if she understands division by fractions.
D. Not enough information to determine.

Less than half of the students answering this question selected B as the correct response, and a third recognized that Sue does not have a good understanding of division by fractions.

Communicate mathematical concepts, processes, and symbols (Indicator 6)

This indicator required communication, therefore students were given the following instructions.

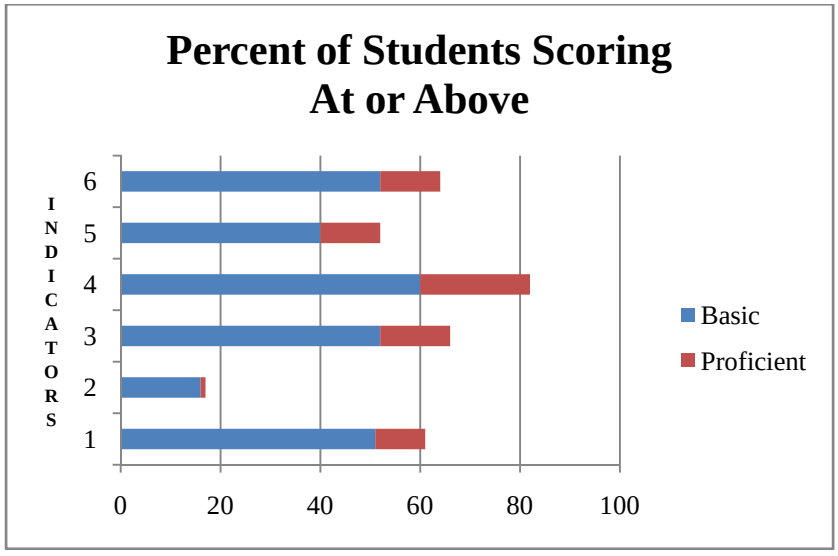
On a sheet of notebook paper, answer only one of the following questions.
1. **Explain** why multiplication does not always result in a larger number than the original two numbers and why division does not always result in a smaller number than the original two numbers.
2. You have 24 feet of fencing. Explain what dimensions you should use to build a rectangular pen for your pet with the largest area possible. **Justify your solution**.
3. You have been buying gas at Station A because the price is usually cheaper. Station A is 15 miles from your house and the current gas price is $3.49 per gallon. Station B is 5 miles from your house with a gas price of $3.69 per gallon. Your car gets 20 miles per gallon and needs 10 gallons. At which store would you purchase gas and why. **Justify your answer**.

Approximately 52 percent of the students scored at the basic level for competency on this indicator.

Discussion

Elementary teachers are often described as being particularly weak in mathematics content. The surprising results from this assessment indicate that all the students indicated deficiencies in mathematics content (except for the 4 secondary mathematics majors). Most of the mathematics content assessed should have been mastered in elementary school. Elementary pre-service teachers might have outperformed secondary and special education majors because this is the mathematics which they had most recently been exposed to through their required

mathematics course for elementary teachers, although all indications were that the elementary pre-service teachers did not have the level of competency which would be desirable to improve their students levels of performance. Of the secondary majors, excluding mathematics majors, physical education students had the lowest performance on these indicators.



Limitations

Interpreting the intention of the 6 mathematics indicators is left to the discretion of each college/university in the state. Therefore the questions used on the quizzes and the modules developed are not objectively applied to the education population. Additionally, selecting 6 of 10 being "good enough" to indicate proficiency was selected as reasonable given the task of meeting these indicators for all graduates within the time frame. The results obtained by examining the data should not be generalized to a larger population but are interesting just for assessing the level of competency and finding common errors and misunderstanding.

Next Steps

Currently there are study guides and links to interactive websites on the topics listed under each indicator. Working with graduate students from the instructional design department, computer modules are being developed to "remediate" students. These modules consist of videotaped scenarios and instructional components designed to "teach" or review mathematical concepts and terms from the indicators. Students who do not meet initial proficiency will be required to access these modules, and time spent within each will be recorded. A testing matrix is being designed which require students to move through levels of question difficulty. The difficulty level is dependent upon correct or incorrect responses from the student. Indicators will

be tied to selected classes according to student content major so instructors can insist students visit the modules

The National Mathematics Advisory Panel acknowledged that there is some evidence that tutorials, specifically computer assisted instruction combined with drill and practice has had a positive impact on mathematics performance (National Mathematics Advisory Panel, 2008). The purpose of the computer modules being developed is twofold: to increase the mathematics performance of all pre-service teachers who are not meeting the state mathematics indicators, and to determine the feasibility of using similar computer modules to instruct students.

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Dr. S. Kathy Westbrook returned to school (Auburn) following more than 17 years in the high school classroom and earned her masters in Applied Mathematics and a Ph.D. in mathematics education in 2005. As a graduate student, she was involved with TEAM-Math as the first project manager and worked several summers at the teacher professional development institutes. Dr. Westbrook spent one year as a visiting professor at Columbus State University before moving to Mobile to join the faculty at the University of South Alabama as an assistant professor. At USA, Dr. Westbrook has a joint appointment with the College of Education and the Mathematics/Statistics Department.