Algebra-Related Misconceptions Identified in a First-Year Engineering Reasoning Course

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Melissa Morris is currently a Teaching Associate Professor for the Freshman Engineering Program, in the Benjamin M. Statler College of Engineering and Mineral Resources at West Virginia University (WVU). She graduated Summa cum Laude with a BSME in 2006, earned a MSME in 2008, and completed her doctorate in mechanical engineering in 2011, all from WVU. At WVU, she has previously served as the Undergraduate and Outreach Advisor for the Mechanical and Aerospace Engineering department and the Assistant Director of the Center for Building Energy Efficiency. She has previously taught courses such as Thermodynamics, Thermal Fluids Laboratory, and Guided Missiles Systems, as well as serving as a Senior Design Project Advisor for Mechanical Engineering Students. Her research interests include energy and thermodynamic related topics. Since 2007 she has been actively involved in recruiting and outreach for the Statler College, as part of this involvement Dr. Morris frequently makes presentations to groups of K-12 students, as well as perspective WVU students and their families.

Dr. Morris was selected as a Statler College Outstanding Teacher for 2012, the WVU Honors College John R. Williams Outstanding Teacher for 2012, and the 2012 Statler College Teacher of the Year.

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Background:

Students join engineering programs with a significant level of knowledge; some of this knowledge is correct and some incorrect [1, 2]. Students' pre-instructional knowledge is defined as "preconceptions". It has been shown that educators need to assess these preconceptions, because they affect new learning, especially since learning depends on whether the new knowledge agrees with or contradicts existing preconceptions [2].

Preconceptions that are consistent with the concepts learned in class are called "anchoring conceptions"[3]. Preconceptions that are inconsistent with concepts learned in class are termed "alternative conceptions" or "misconceptions"[3]. Making errors is an integral part of the learning process. However, misconceptions could lead to impairments in students' ability to understand and learn new material [2].

Two main forces are driving students' transfer out of engineering: students' lack of interest or loss of interest in engineering, and students' difficulty in their math courses [4-7]. Helping students succeed in their math courses is essential to improving the retention of students in engineering. This paper summarizes the results of a study aimed at improving students' math and engineering reasoning skills. In this portion of the study, the investigators evaluated students' misconceptions and issues related to solving math and engineering problems.

Methodology:

First Year Engineering Program: At West Virginia University (WVU), the Benjamin Statler College of Engineering and Mineral Resources accepts students into one of three degree tracks: engineering track 1 (for calculus ready students), engineering track 2 (for pre-calculus ready students), and engineering track 3 (students ready for college algebra). These tracks are tailored to provide students with the academic preparation necessary for success in their first year at WVU. Once students complete 6 courses (Calculus 1, General Chemistry, English, Engineering Seminar, Engineering Problem Solving 1, and Engineering Problem Solving 2) with a C or better, they will move from the Fundamentals of Engineering Program to an engineering department to complete their bachelor degree.

Participants: One hundred students enrolled in the First Year Engineering Program at WVU participated in this study. All students were enrolled in an Algebra course at the time of the study; all students were enrolled in the engineering track 3. This study was reviewed and approved by the WVU Institutional Review Board.

Analysis of student work: All students completed a series of worksheets that assessed their mathematical and engineering problem solving skills. Each week, practice worksheets were distributed to all students, and one week was given to complete each assigned worksheet. The math topics evaluated in these worksheets are summarized in Table 1.

Table 1. Math Topics Evaluated in the Study

Topic	Topics Evaluated in Practice Worksheets
1	Order of Operations
2	Polynomial Addition/Subtraction
3	Factoring by Grouping
4	Rational Expressions
5	Radical Equations
6	Solving Quadratic Equations
7	Complex Numbers, Real Roots, and Inequalities
8	Equation of a Line and Circles
9	Evaluating and Graphing Functions
10	Fundamental Theorem of Algebra Skills Practice, Inverse Functions
11	Exponential Functions and Logarithmic Functions
12	Systems of Linear Equations
13	Solving Systems of Equations with Matrices

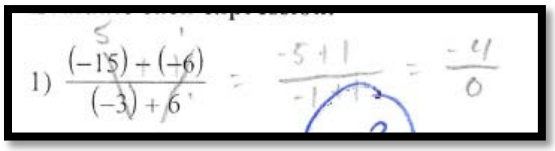
Each week, the worksheets were graded, and all solutions were scanned and stored in a database. Weekly quizzes were used to assess students' learning. Areas of difficulties were identified after manually grading quizzes and worksheets.

Results:

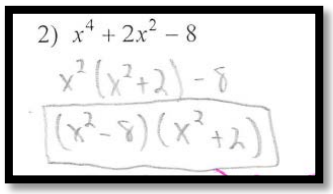
Two main issues were identified in the graded worksheets: students' difficulties with performing basic math operations and students' misconceptions.

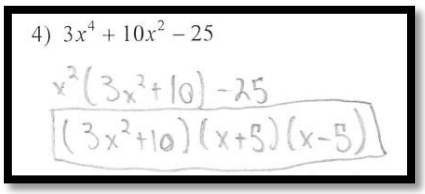
Examples of misconceptions and calculation errors found in students' work:

a) Students incorrectly factored 3 out

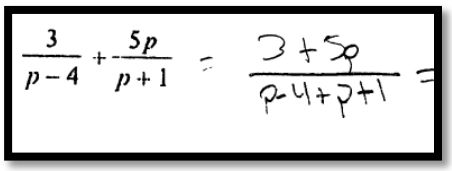


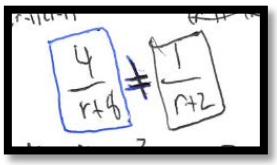
b) Students incorrectly factorized an expression, by selecting an incorrect common factor

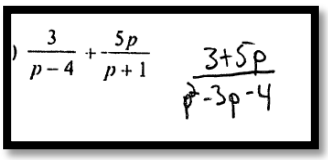




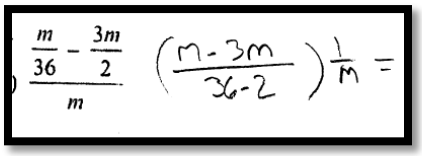
c) Lack of knowledge on how to simplify a rational expression



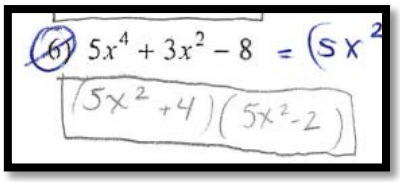


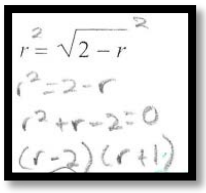


d) Unable to identify a common denominator

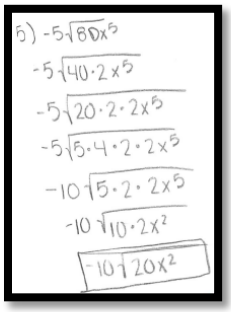


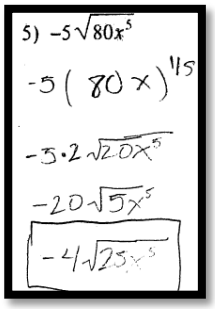
e) Wrong factorization





f) Unable to simplify problems with radicals





Discussion:

The use of web-based math learning systems, such as ALEKS (Assessment and Learning in Knowledge Spaces), is simplifying teachers' job by eliminating the excessive grading associated with teaching math and science courses. However, because teachers are no longer manually grading students' work, they are unaware of students' areas of difficulty. Another concern is the fact that because students are no longer solving problems by hand (they are mainly solving problems in the computer), they are losing the ability to solve problems and the capacity to reason through problems.

In this study, students' misconceptions and errors in calculations considerably hampered students' ability to solve math and engineering problems. Some of the students enrolled in the course struggled performing basic mathematical operations such as multiplication and working with negative signs. Students also had issues manipulating and simplifying rational and radical expressions. Some students were unable to factorize polynomials.

In general, students' misconceptions must be addressed in order to improve their math and engineering problem solving skills. Concept tests, which are short tests used to assess students' prior knowledge and to analyze students' understanding of concepts, can be used as a diagnostic tool to identify misconceptions. Practice problems that target misconceptions need to be develop to make students aware of their misconceptions and to correct them.

Conclusion:

To improve students' math and engineering problem solving skills, errors in calculations and students' misconceptions must be addressed. Students need to master basic mathematical concepts to be able to solve advanced math and engineering problems.

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