

Instructional Assessment Methods to Enhance Conceptual Knowledge: a Preliminary Investigation

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Abstract

A pilot study was performed during the spring 2011 semester to investigate the effect of alternative methods of student assessment on conceptual knowledge transfer relating to the topic of buoyancy. A group of sophomore-level undergraduate engineering students at the University of Wisconsin – Stout (N=52) were evaluated in their performance on pre- and post- assessments. Students who performed well on proportional/conceptual reasoning questions during pre-assessment activities performed better on post-assessment activities than the control group of students who were not prompted with proportional/conceptual reasoning type questions in the pre-assessment ($z = 1.643$, $p < 0.1$).

Keywords: Engineering, Teaching Quality, Critical Thinking

Introduction

Conceptual knowledge is defined as understanding the “principles governing a domain and the interrelations between units of knowledge in a domain” (Rittle-Johnson, 2006). In the field of engineering it is necessary to have a firm grasp of conceptual knowledge in order to accurately predict the effects of design changes on a final product (Streveler, et. al, 2008). Often the instructional assessment methods employed in engineering education are assignments/problems which require students to apply a particular solution procedure to determine a numerical value. However, these types of assessments may not be the most effective strategy for helping students to develop the deep level of conceptual knowledge necessary to perform well as a practicing engineer.

It is hypothesized that instructional assessment methods which require proportional/conceptual reasoning, rather than numerical calculation, may increase students’ understanding of conceptual knowledge. Anecdotal experience has shown that when students are faced with calculation based assignments/problems, they often seem to run through numerical calculation procedures without thinking critically about the concepts involved. By removing numerical values from assignments and asking students to reason their way to answers, rather than calculate their way to them, it is hypothesized that students will develop a deeper level of conceptual knowledge.

Methods

For this study, buoyancy has been chosen as the subject in which to investigate the impact of assessment methods on student learning. Buoyancy is a topic familiar to common experience and is therefore a topic for which students will likely have preconceptions which they must overcome. Additionally, buoyancy is a subject which can be understood on the basis of foundational concepts (force, pressure, etc.) without the need for a higher level understanding of fluid mechanics.

The research subjects employed in this study are students from a sophomore-level course in engineering statics (N=52). These students are familiar with the concepts of force, pressure, and free body diagrams; topics which are prerequisite for understanding buoyancy. However, these students have not yet formally studied fluid mechanics, and as such, any preconceptions they have are not the result of any formal education in the subject.

Each of the students was asked to read a one page handout out which introduces the topic of buoyancy as a way of *learning* about the subject. Immediately following this, students were asked to complete a short assignment (Activity X) involving the topics they just *learned*. In Activity X students were asked to calculate the tension force in a string which holds a StyrofoamTM block

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under water such as that shown in Figure 1(a). This numerical calculation problem is similar to the types of instructional assessment often employed in engineering education.

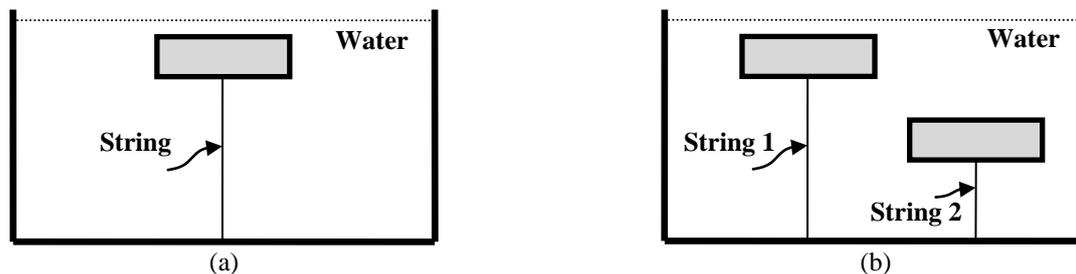


Figure 1: Numerical calculation (a) and proportional reasoning (b) questions from Activity X.

Approximately half of the students in the study (N=24) were randomly selected and given a version of Activity X which included an additional proportional reasoning question. The students were asked to compare the tension forces on two identical Styrofoam™ blocks held under water at different depths with a string as shown in Figure 1(b).

The Activity X assessments were collected by the instructor and the students' performance recorded. These activities were then returned to the students the following class period along with an answer key for the corresponding version of the activity.

During the third class period, students were asked to complete another activity (Activity Y) in which they considered a wooden block and Styrofoam™ block submerged at the same depth under water. Students were asked to explain why the Styrofoam™ block is observed to reach the surface of the water faster than the wooden block when released simultaneously. These activities were collected and student performance analyzed relative to the version of Activity X assigned.

Results

Student performance on the numerical calculation question from Activity X was very high, with only 3 of 52 students answering this question incorrectly. These same three students also answered Activity Y incorrectly and have not been included in the results that follow.

The results of this study are summarized in Table 1 with the students classified into three groups. Of the students who were assigned only the numerical calculation question on Activity X (Group A), 44% correctly answered the question on Activity Y. Of the students who were assigned both the numerical calculation and proportional reasoning questions on Activity X (Group B), 64% correctly answered the question on Activity Y. The difference between these two groups is not statistically significant, however ($z = 1.339$). Therefore, it cannot be concluded that students who were assigned proportional reasoning questions performed better on Activity Y.

Table1: Performance on Activity Y relative to performance on Activity X.

	Group Size Number of Students	Activity X Performance		Activity Y Performance	
		Numerical Calculation Question	Proportional Reasoning Question	Number of Correct Responses	Percentage of Correct Responses
Group A	27	Correct	Not Assigned	12	44
Group B	22	Correct	Assigned	14	64
Group C	14	Correct	Correct	10	71

When comparing students who correctly answered the proportional reasoning question from Activity X (Group C) to those who were assigned only the numerical calculation question (Group A), a statistically significant difference does emerge with 71% of students in Group C answering

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Activity Y correctly compared to 44% in Group A ($z = 1.643$, $p < 0.1$). This result suggests that conceptual knowledge may be enhanced for students who perform well when prompted with a proportional reasoning question, compared to students who are only assigned a numerical calculation question. Larger sample sizes are needed to increase confidence in this conclusion.

In addition to continued data collection, it is of interest to further investigate the mechanisms by which performance may be improved on Activity Y for students who performed well on the proportional reasoning question. Is this merely the result of having become familiar with proportional/conceptual reasoning type questions? Or, is this an indication that students have indeed developed a deeper level of conceptual knowledge? Future studies will seek to answer these questions through the use of think-aloud methodologies.

References

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Derek Wissmiller is an Assistant Professor at the University of Wisconsin – Stout in the Department of Engineering and Technology. Dr. Wissmiller's current research interests include the investigation of student learning and assessment methods in engineering education. He earned his PhD in Mechanical Engineering from Iowa State University in 2009 and his MS in Mechanical Engineering from the University of Wisconsin – Madison in 2006.