Statics Concept Questions for Enhancing Learning

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Abstract

Students in science, math, or engineering classes often focus on plugging numbers into equations rather than understanding basic concepts. The book *Peer Instruction* by Eric Mazur (1997) helps physics teachers move students from juggling equations to actually thinking and learning the concepts of physics by use of concept questions. However, Mazur's methodology has not seen widespread use in teaching statics. This paper reports the initial development of concept questions to support active learning methods in statics classes**. T**he development of statics' concept questions at different levels of Bloom's taxonomy, their use in statics classes at two different institutions, and initial results are described.

I. Introduction

Educational research suggests many benefits of incorporating active engagement methods like cooperative learning, peer instruction, and critical thinking exercises in our classes (Hake, 1998; Johnson et. al., 1998; Mazur, 1997). However, adopting these techniques is a challenge for many engineering educators. Traditional problem-solving classes like physics and engineering mechanics pose their own unique challenges to using these active engagement strategies. Often students learn how to use formulas in carefully defined problems but avoid learning the broader framework or conceptual basis of the subject. Charles Misner, in a foreword to Mazur's book *Peer Instruction* (1997), writes "The idea that physics is all equations is such an established myth among students that many of them refuse to think if they can find equations to memorize." This sort of student "learning" can also happen in many engineering classes.

However, Mazur's (1997) powerful data provide strong reasons to adopt his methodology of using concept questions and student interaction to provoke students into more comprehensive understanding and learning. The questions tend to probe deeper understanding of a concept rather than simply plugging numbers into equations. Mazur used diagnostic tests to assess student learning in introductory physics for both experimental (using concept questions and student interaction) and control groups by recording pre- and post-instruction performance. He found significant gains in student learning (as measured by use of established diagnostic tests for physics) as a result of his experimental conditions. In addition to using diagnostic tests, Mazur compared student performance on identical final examinations (given six years apart) for a conventionally taught physics class versus an experimental class. He also found a "marked improvement in the mean, as well as a higher cut-off in the lower-end tail" (p. 16). This improvement of the poor to average student's learning is an important effect. Concept questions can be used for active cooperative learning activities during class and as exam questions. Mazur suggests that exams contain a combination of traditional computational problems and conceptual questions. This combination makes students study fundamental principles in addition to more traditional homework problems focused on use of equations.

II. Concept Questions In Statics

Developing concept-questions for statics is part of a larger project focused on development, evaluation, and national dissemination of instructional materials for statics. These instructional materials are based on advances in undergraduate education and effective educational practices proven to enhance student learning. The materials include specification of expected student learning outcomes, mini-lecture critical content, cooperative learning activities, and classroom assessment techniques. A bank of conceptual questions for quizzes, cooperative-learning exercises and tests are being developed. This paper reports on the current state of development of these quizzes and their use in statics classes at two different institutions. One institution is using the Hibbeler statics text (1998) and the other is using the Beer and Johnston (1996) text. However, the concept questions are generic, i.e., not tied to any particular textbook.

We are working to develop a question bank for each major topic typically covered in statics classes. There are two important facets to the question banks being developed. First, the questions will be linked to the various levels of Bloom's Taxonomy (Bloom, 1956). Second, questions involving engineering design will be included. Our goal is to construct a rich mixture of questions requiring and encouraging student's intellectual effort on all Bloom's levels. The taxonomy (knowledge, comprehension, application, analysis, synthesis, and evaluation) provides a useful structure in which to categorize questions. A generalized resource on designing questions at all levels of Bloom's taxonomy is available on the web (MCQ, 1995) and provided help in creating the statics questions. A sample set of questions and their relationship to Bloom's taxonomy is included in the appendix.

III. Initial Results

The questions were used in the fall 1999 semester in two sections of statics at North Dakota State University (enrollments of 50 and 100 engineering students) and one section of 22 engineering technology students at Arizona State University East. As suggested by Mazur, concept questions are used in two different ways. During the typical class period, a set of concept questions is given after a mini-lecture (15 to 20 minutes). The questions probe the student's understanding of the subject just covered by the mini-lecture (which may contain simple examples, etc.). The questions are intended to require a minimum of calculation and without significant manipulation of formulas. All are posed as multiple choice problems. The students are asked to answer the question individually, based on their own reasoning and understanding of the material. Then the students are instructed to talk over the questions with the people sitting around them. These informal groups discuss the questions and answers for about two minutes. Then students record another set of answers to the questions.

In the NDSU sections, students used optical scan sheets to record their answers. Data analysis indicates that when students work independently, they select correct answers on approximately 60% of the concept questions. However, after discussing the questions amongst their peers, the percentage of students getting the questions correct goes up to 80%.

Mid-semester feedback, i.e., formative assessment, was also solicited from the students. Students were asked to judge the usefulness of the various teaching strategies used in the statics classes using a five item scale (A - very useful, B - useful, C - neutral, D - not useful, E - not useful at all). The student responses for items related to concept questions are shown in Table 1below.

TABLE 1. Mid-semester Feedback from Statics Classes

A	B	C	D	E	A+B	Survey Item
Percentage responses from a section of 42 students at NDSU						
31	38	26	5	--	69	Giving daily conceptual quizzes for enhancing critical thinking
29	41	14	17	--	70	Working on conceptual quizzes in group for enhancing team work and learning
Percentage responses from a section of 96 students at NDSU						
26	40	26	4	4	66	Giving daily conceptual quizzes for enhancing critical thinking
34	33	21	8	4	67	Working on conceptual quizzes in group for enhancing team work and learning
Percentage responses from a section of 21 students at ASU East						
45	35	15	--	5	80	Giving conceptual quizzes for enhancing critical thinking
38	33	14	10	5	71	Working in groups on conceptual quizzes

ASU East student written comments regarding the use of concept questions include "keep a mix of questions on mini-exams (1/4 conceptual, ¾ problem solving)," "group participation helps to look at picture from other views," and "more group work in conceptual areas." However, in general, ASU East students did not like the use of concept questions on exams, with only 43% of students rating that item as very useful or useful.

IV. Conclusions

While as instructors we believe that the use of concept questions in engineering problem courses like statics is important, students are harder to convince. In general, only about two thirds of the NDSU students think the questions contribute favorably to their learning. But, the ASU East data may point to part of the reason. ASU East Students did not do well on the exam concept questions, often losing a significant number of points on them. This may have led to the dramatically lower rating for the use of concept questions on the exam as compared to their in-class use. (The NDSU students did not have opportunity to separate out the two different types of concept question occurrences.) Thus, in-class use is less threatening to students and more related to learning. Students probably do not perceive tests as a learning opportunity and are primarily interested in generating a good grade.

Writing good concept questions is not a trivial task. Both instructors found it time consuming to write these questions. Obviously, the concept questions will evolve with time and improvement in the questions will result in a better student learning experience. The use of Bloom's Taxonomy is an additional twist that should result in better use of the questions in the classroom environment. For instance, questions based on the lower levels of the taxonomy should be used in the classroom when first introducing the material. Then as students mature in their understanding of the content (say by the exam), questions residing in the higher levels of the taxonomy can be used.

Acknowledgements

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Appendix

The following are sample questions from statics that address various levels of the taxonomy. Guidelines suggested in "Designing and Managing Multiple Choice Question" found at www.uct.ac.za/projects/cbe/mcqman were used in developing the questions.

Level 1: Knowledge. This level simply requires the recall of acquired knowledge. A test at this level alone can easily become a "Trivial Pursuit" exercise!

Question: Define a dot product of two vectors **A** and **B**, where $\mathbf{A} = A_x\,\mathbf{i} + A_y\,\mathbf{j} + A_z\,\mathbf{k}$ and $\mathbf{B} = B_x\,\mathbf{i} + B_y\,\mathbf{j} + B_z\,\mathbf{k}$.

a) $(A_x + B_x)\,\mathbf{i} + (A_y + B_y)\,\mathbf{j} + (A_z + B_z)\,\mathbf{k}$

b) $A_x B_x + A_y B_y + A_z B_z$

c) $A_x B_x\,\mathbf{i} + A_y B_y\,\mathbf{j} + A_z B_z\,\mathbf{k}$

d) $(A_x + B_x) + (A_y + B_y) + (A_z + B_z)$

Explanation: In this example, the definition of a dot product of two vectors is used to select (b). This also shows that the resultant of a dot product is a scalar quantity and not a vector.

Level 2: Comprehension. At this level knowledge of facts, theories, procedures, etc., is assumed and questions test for understanding of knowledge.

Question: Part of a nail (4 cm long) is sticking out of the wall at A in the y-direction, and force F is applied to the nail, as shown in the figure. It is possible to determine: (select all correct choices)

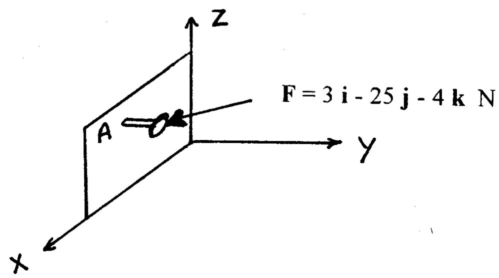
a) The angle between the force and the nail.

b) The amount of deflection (bending) of the nail.

c) The magnitude of the force pushing the nail in the wall.

d) Maximum bending moment at A.

e) The insertion distance of the nail in the wall.



Explanation: From the sketch and knowledge about dot products, select a, c, and d.

Level 3: **Application.** At this level of competence, prior knowledge and understanding of the subject is assumed and one is expected to apply this knowledge and understanding. Calculations based on known formula are typical for this level. For example, calculation of the three quantities mentioned in the previous comprehension level question would be at the application level.

Question: Please refer to the previous question and find the magnitude of the bending moment at A.

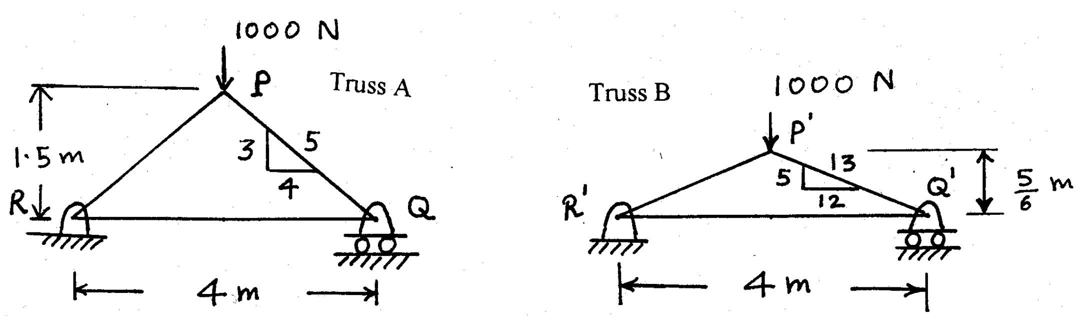
a) 12 N·cm
b) 16 N·cm
c) 20 N·cm
d) 25 N·cm
e) 32 N·cm

Explanation: The y component of the force will not produce any moment as it passes through point A. The x and z components (3 and 4 N, respectively) will produce a bending moment of
5N * 4 cm = 20 N-cm (answer C)

Level 4: **Analysis.** This competence level refers to the ability to break down material into its component parts so that its organizational structure may be understood. These learning outcomes represent a higher intellectual level than comprehension and application because they require an understanding of both the content and structure of the material.

Question: Analyze and compare the trusses in Figure 4. They have the same span and the same vertical loading but different heights. Select the true statement about the forces in the truss members.

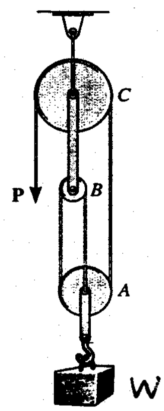
a) Forces in all the members of the truss A are higher compared to the forces in the corresponding members of the truss B.
b) Forces in all the members of the truss B are higher compared to the forces in the corresponding members of the truss A.
c) Forces in the corresponding members of the trusses A and B are the same.
d) None of the above.



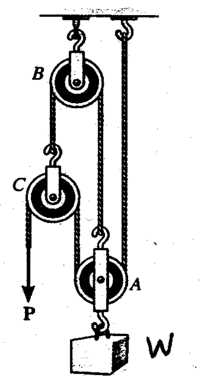
Explanation: Analysis of the top joint indicates that the forces in PQ and RQ are equal and are 500 N. Thus, member PQ will develop a force equal to 5/3 (or 1.67) times 500 N (half of the vertical load on the truss), while the member $P'Q'$ will develop a force equal to 13/5 (or 2.6) times 500 N. Correspondingly, loads in the other members of Truss B are also higher. Hence, B is the correct response.

Level 5: <u>Synthesis.</u> This competency level refers to the ability to put parts together to form a new whole. Learning outcomes in this area stress creative behaviors, with major emphasis on the formulation of new patterns of the knowledge structure. Questions at this level are initially more suitable for homework, group activity, or descriptive type of exam. However, they can be posed in a multiple choice format similar to the Fundamentals of Engineering licensure exam.

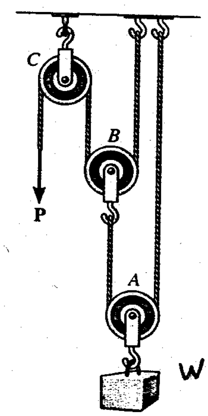
Question: Design an arrangement of three pulleys to lift heavy loads with the least effort.



P = W/3
(R)



P = W/4
(S)

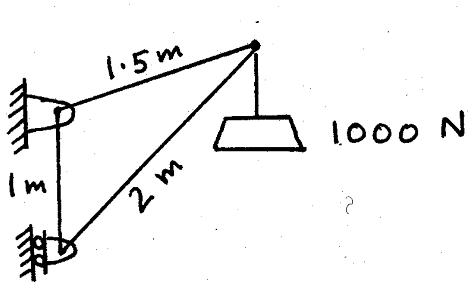


P = W/4
(T)

Explanation: Analysis of free body diagrams of the pulleys indicate that arrangement S or T will be better.

Level 6: <u>Evaluation.</u> This level of competency refers to the ability to judge the value of material for a given purpose. The judgments are to be based on definite criteria. Learning outcomes in this area are highest in the cognitive hierarchy because they contain elements of all other categories, plus conscious value judgments based on clearly defined criteria. The types of questions at this level are more suitable for <u>group</u> projects. However, instructors can devise multiple choice questions where data and choices are given with students asked to recommend a solution.

Question: Determine the forces in the members and select sizes of the wooden members so the truss is safe and costs the least.



Explanation: This question requires analysis and research. The research will involve the common sizes of wood available, their strengths in compression and tension, and cost. Based on this analysis, students should recommend suitable member sizes and the truss's total cost.

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Concept checking can help the teacher to see beyond doubt that the student has understood. Asking the class â€˜do you understand?â€™ is not so useful as it doesnâ€™t demonstrate the learnersâ€™ understanding. What can it be used for? The most obvious use for concept checking questions is vocabulary. They can also be useful for grammatical structures and ideas.Â 3. Concept checking questions Are the houses interesting or boring? interesting Are they attractive or ugly? attractive Are they normal or strange? strange Are they old-fashioned or modern? old-fashioned. Different types of concept checking questions. Display questions and referential questions.Â waoh !have learnt so much and i apply these tips in teaching mathematics. LikeLiked by 1 person. Reply. Concept learning describes the process by which experience allows us to partition objects in the world into classes for the purpose of generalization, discrimination, and inference. Models of concept learning have adopted one of three contrasting views concerning category representation. In prototype theories, the concept learning process is assumed to yield an abstract representation corresponding to the central tendency of the category exemplars on each of the dimensions of variation. Concept learning, also known as category learning, concept attainment, and concept formation, is defined by Bruner, Goodnow, & Austin (1967) as "the search for and listing of attributes that can be used to distinguish exemplars from non exemplars of various categories". More simply put, concepts are the mental categories that help us classify objects, events, or ideas, building on the understanding that each object, event, or idea has a set of common relevant features. Thus, concept learning is a