Spicing up Statics Lectures with Concept Questions and ‘Around Town’ Assignments

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Abstract

Concept questions and ‘around town’ assignments were incorporated into Penn State’s introductory statics course during the Fall 2001 semester in an attempt to reinforce key concepts, catch student’s attention, provide in-class feedback, and extend textbook work to ‘real world’ applications without major changes to the current course format. The concept questions are a series of multiple choice, no calculation questions, each addressing a single statics concept. In the lecture recitation format 1 to 2 questions were used in the middle and the end of each lecture loosely following Eric Mazur’s Peer Instruction model. By holding up one of 4 colored index cards (provided at the beginning of the semester), the instructors received immediate feedback on the range of student understanding, opening the door to timely discussions targeted to the needs of an individual class. The use of ‘think-pair-share’ proved quite useful with the concept questions as well. In addition, students were charged with the optional task of looking ‘around town’ for real world examples related to the specific lecture topics. These student submissions (either hand sketched or digitally photographed) provided a handy recap of the previous topic at the beginning of the next lecture. The one or two most interesting / most relevant applications received a small prize, providing incentive for participation and increasing enthusiasm and interest in the topics among the class. While they don’t represent overall course reform, both the concept questions and the ‘around town’ assignments are easy to implement into any existing statics course to reinforce basic concepts, provide immediate student comprehension feedback and foster enthusiasm among the students.

Background

During the Fall 2001 semester, the majority of students enrolled in Statics at Penn State-University Park were taught using a lecture/recitation format. Using this delivery method a faculty member presented one lecture each week to a large class of students (>150) and teaching assistants presented corresponding problems during the remaining two weekly class sessions to the students in smaller sections (approximately 40 students in each section). A set of notes that were reflective of the material covered during the lecture was distributed to the students at the start of each lecture class.

This method has certain attributes that were extremely valuable: i) uniformity—all sections would cover the same material and to the same depth; ii) complete coverage—the notes would ensure that students would have the level of detail of the concepts prior to the recitation sessions; iii) efficiency of lecture class time—rather than constructing the notes on the board or overhead the lecture instructor spent class time emphasizing certain details in the notes, offering alternate explanations, elaborating on subtleties, and connecting the notes to experience.
We recognized during the planning stages of the course that this method of delivery would provide some opportunities for students to discuss and interact with the recitation instructors regarding the application of the concepts to problems but few opportunities would present themselves for the lecture instructor to gauge the students’ daily understanding of the concepts. This would place an increased burden on the less experienced recitation instructors (teaching assistants) to address misconceptions. Furthermore, there was concern on the part of the lecture instructors that since the notes were made available, students might have little incentive to attend the lectures, particularly if the students felt that the notes were covered verbatim. By using the ‘concept question’ approach described by E. Mazur in Peer Instruction and ‘around town’ assignments we were able to address some of these concerns regarding the lecture portion of the course.

Concept Question and Peer Instruction Approach

Briefly, the ‘peer instruction’ approach detailed by Mazur consists of planned, intermittent opportunities for students to assess their own understanding and to articulate their understanding to their peers and the instructor, and for the instructor to obtain immediate feedback about the level of student understanding of key concepts. These learning opportunities are placed at specific times in each lecture with the frequency depending on the number of concepts introduced or reviewed during a particular lecture. After a concept is covered, a question that focuses on that single concept is projected on the overhead for the entire class to read. After two minutes, the instructor calls for the student responses: raising hands, or raising lettered index cards. If the responses reveal that the majority of students have grasped the concept, then the instructor quickly summarizes why the one response is correct and the others are not. If the student responses are varied then the instructor either elaborates on the concept, or asks the students to turn to each other to discuss their responses. After this discussion time, the instructor again asks the students to indicate their responses, which have now either been revised or reinforced.

Mazur’s approach, developed for his physics courses, has been adopted by other instructors particularly those in other physical sciences, such as chemistry, biology and astronomy. Danielson and Mehta are developing engineering mechanics curricular materials that incorporate this approach and link the concept questions to Bloom’s Taxonomy. Surely, those who have adopted this approach identify with Mazur when he recounts his observations of students’ misunderstandings of fundamental concepts and his motivation to improve student learning. He offers compelling evidence of the success of the concept question and peer instruction method with student results from his physics courses, as well as advice on how to write the questions and implement the technique. The catalogs or banks of questions emerging from the physical science fields closely follow the guidelines described by Mazur about what makes a good concept question and general recommendations for how to write multiple-choice questions. Our review of these references and the available examples facilitated the implementation and adaptation of this method to our Statics course.

When applying this approach to our 50-minute lectures for Statics, we made a few modifications. Because the class size was large enough that letters on index cards in the back row could not be read, brightly colored index cards were used in place of the lettered index cards. This meant that students could see their classmates’ responses and possibly change their choice to match the majority, thus giving the instructor a false sense of student understanding. During the first day
we emphasized that students were not penalized for incorrect responses and that they were more likely to benefit by indicating the response that represented their understanding even if it differed from others in the class. That seemed to take care of the potential problem.

For most of the Statics lectures, two concepts were covered per class period. After the concept was presented, the concept question was posed. If the sea of colored index cards varied significantly, the instructor took one of three courses of action:

1. Ask students to discuss their responses with each other for 2 minutes and then call for their new responses;
2. Elaborate on the concept, ask them to discuss their responses with each other for 2 minutes, and then call for their new responses;
3. Select student explanations for both correct and incorrect responses and discuss them with the class.

The first approach worked best if the student responses were bipolar and one of the selected responses was the correct one. The latter two approaches tended to work when the student response varied widely. Approach 2 was appropriate if the instructor felt that a better explanation on his/her part was warranted, whereas approach 3 was used to hone in on the misconceptions students had about the concept, or to initiate instructor-student discussion.

Observations From Concept Question Novices

Writing good concept questions takes a significant amount of time, but they are worth the effort. The tips provided by Mazur and the multiple-choice writing guidelines found online were very helpful. Even so, occasionally a less than perfect concept question made it to the class. Example 1a illustrates this point. The question is fine, but the choice of responses does not differentiate those who fully understand from those with partial understanding. A student who is certain that condition 1 will yield the result of zero, but not so certain that condition 2 will yield a zero result, or vice versa is likely to select c. He or she may feel good about selecting the correct response, but may have a false sense of understanding. Likewise the instructor did not get the best information about the students’ understanding. A better set of conditions and multiple choice responses is shown in Example 1b.

Example 1a.
The moment of force $\mathbf{r} \times \mathbf{F}$ about an axis which is described by unit vector $\hat{\lambda}$ will be zero (i.e., $(\mathbf{r} \times \mathbf{F}) \cdot \hat{\lambda} = 0$) if
1. $\mathbf{r}$ and $\mathbf{F}$ are parallel vectors
2. $\hat{\lambda}$ lies in the same plane as $\mathbf{r}$ and $\mathbf{F}$
3. $\mathbf{r}$ and $\mathbf{F}$ are perpendicular vectors
4. $\hat{\lambda}$ is perpendicular to $\mathbf{r}$ and $\mathbf{F}$
   a. 3 only
   b. 4 only
   c. 1 or 2
   d. 3 and 4

Example 1b.
The moment of force $\mathbf{r} \times \mathbf{F}$ about an axis which is described by unit vector $\hat{\lambda}$ will be zero (i.e., $(\mathbf{r} \times \mathbf{F}) \cdot \hat{\lambda} = 0$) if
1. $\mathbf{r}$ and $\mathbf{F}$ are parallel vectors
2. $\hat{\lambda}$ lies in the same plane as $\mathbf{r}$ and $\mathbf{F}$
   b. 1 only
   c. 2 only
   d. 1 or 2
Take full advantage of the occasions when mass confusion about a concept arises as indicated by a wide variety of student responses. These are great opportunities to discover and eradicate student misconceptions. Example 2 is the type of problem that is likely to lead to a variety of responses. For these cases, select students with incorrect responses to explain why they chose the answers they did. List those explanations on an overhead and discuss where the reasoning falls apart. For this example, common misconceptions occur with the definitions of axial tension and compression, and the inability to recognize zero-force members. After this kind of example, try a similar question but use member BC and change the possible responses.

Example 2.

The truss is subjected to a load that moves from joint A to joint C.
When the load moves from A to C, the member AB
a. remains in tension
b. remains in compression
c. changes from tension to compression
d. changes from compression to tension

‘Around Town’ Assignments

In addition to the incorporation of concept questions, ‘around town’ assignments were initiated in the fall semester statics lectures to encourage students to expand their view of the relevance of course material beyond the classroom. The goal of the basic statics course is to enable students to apply principles learned in prior math and physics classes to the modeling of physical engineering systems. However, because the course is primarily focused on problem solving, too often students view the content as ‘just another set of mathematical exercises’ and fail to make the connection between principles discussed in class and the behavior of the world around them. The ‘around town’ assignments attempted to facilitate the students to discover the variety of practical engineering applications of basic statics concepts.

Several times throughout the semester, at the end of the weekly lecture, students were challenged to search ‘around town’ for a unique example or examples of objects, actions or situations that illustrate the current topic. They were given a week to either hand sketch an illustration of their example or borrow a digital camera from the university’s audio/visual department to photograph their example. It was required that each photo or illustration be accompanied by a short description, highlighting why the example was selected and how it related to the current class topic. After all the entries were collected, the most unique / most original / most interesting examples were selected and shared with the class at the beginning of the next lecture. The names of the students submitting the winning entries were announced in class and if these students were present, they received a small prize. In addition to livening up the class with this lighthearted...
competition, presentation of the winning entries served as an excellent recap of the previous lecture before beginning a new topic. These entries served to generate conversation regarding the applicability of statics principles to a variety of real world situations. And entries that were ‘not quite correct’ (presented without student names) generated discussions regarding common misconceptions.

In the first ‘around town’ assignment, students were instructed to ‘Take a digital picture or draw a sketch of the most interesting thing you can find around town that can be described by a vector.’ The response to this request was overwhelming with nearly 80 students of the 450 enrolled among the various sections participating. As you can see by the varied winning photo entries given below, shown along with the student explanations, some students chose very traditional applications while others got rather creative.

This picture can be described by a vector. The ribbon shows the air flow from the fan. Since the air has a velocity (magnitude and direction), it can be described with vectors.

In this picture taken from the Daily Collegian, Penn State kicker David Royer applies a force, a vector, to a football in a game against Perdue last year. The football is given an acceleration and a velocity, both vectors, due to the kick.

For the purpose of explanation we will call the man the left Joe and the man on the right Gary. There are various and sundry force vectors in this picture. Joe's hand for instance has an applied force by him toward the back of the picture and a force from Gary's hand that points out of the picture. These forces seem to be balanced at the moment, but the most casual observer can see that Joe is going to win!
Each ‘around town’ assignment was meant to be narrow enough to keep the attention focused on one specific concept, but broad enough to encourage a variety of creative responses. While the ‘vector’ assignment discussed above produced wide variety of focused responses, a later assignment intended to focus on free body diagram sketches and support reactions was not nearly as effective. This assignment instructed students to ‘Take a digital photo, or draw a realistic sketch, of the most unique support you can find around town. Include a sketch of the forces and/or couples acting on the body attached to the support.’ Because the wording of the request highlighted the supports, the emphasis on reducing a realistic problem to a simplified free body diagram was lost. While the entries did not focus on the intended concept, they still fostered interesting discussion regarding the applicability of class concepts to real world applications.

An ancillary benefit that resulted from these around town assignments is the increasing data base of digital examples that can now be used as illustration in future semesters or to enhance topics on the course web site.

Summary

The use of concept questions in the lecture portion of a lecture/recitation style large Statics class successfully engaged the students during the lecture sessions, provided immediate feedback to the instructors about the level of student understanding of the key concepts, and provided an opportunity for students to assess their own understanding of the concepts as they were presented and prior to applying them to homework problems. Even though writing concept questions is time consuming, the method can be easily placed into an existing lecture model, as the 2-3 minute concept question interludes do not require major modification to the course.

The use of ‘around town’ assignments in any statics class, large or small, can foster enthusiasm among students and extend textbook work to ‘real world’ applications. And as with the use of concept questions, ‘around town’ assignments can easily be implemented into any existing statics course with very few changes to the current course format.

Bibliography


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