Session 1630

Who Wants to be an Engineer?
-or-
Better Teaching through Game Shows

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Abstract

A 50 (or 60 or 70) -minute lecture is inherently incompatible with the typical attention spans of students. The author has developed a teaching technique that successfully re-captures attention in the classroom. The technique, loosely based on a popular prime-time game show, consists of quizzing a student "on the spot" while allowing a "life-line" of polling the audience for help. The game is enjoyable for students and professor alike, but also allows review, clarification, and reinforcement of concepts. The technique is effective while only requiring minimal preparation and lecture time to be implemented.

I. Introduction

Consider a typical lecture course in engineering. For fifty to seventy minutes, a group of students will sit in one place listening, taking notes, occasionally asking questions. Some students will be paying attention, others' attention will be wandering, and some may be sound asleep.

Many engineering instructors have developed and implemented a range of active learning techniques that are integrated into their lectures. In these cases, students are much more actively engaged, through partner or group discussion, writing, and problem solving for example. The positive benefits of active learning approaches have been documented in many studies and books[1]. Within the context of a typical engineering curriculum, the use of active learning techniques often requires careful balancing against the need to cover a demanding range of course material in a limited amount of time. As well, there are varying levels of experience, comfort, and preparation required of the instructor to effectively implement different active learning techniques on a regular basis.

In this paper the author describes a particular active learning technique that he has found to be quick to prepare, easy and fun to implement, appreciated and enjoyed by the students, and effective at both recapturing student attention and promoting the understanding of concepts covered in lecture. The method was first developed for a class devoted to statics and mechanics of materials and was named "Who Wants to Be a Mechanician?" Based on a popular prime-time television game show "Who Wants to Be a Millionaire,"[2] the game involves calling a student up to the front of the class who is asked a multiple-choice question based on the previous lecture's material.

The game is played roughly in the middle of the lecture. This is deliberately done in an attempt to re-capture the inevitably waning attention of the students, the general nature of which is discussed below.

II. Attention Spans in Lecture Environments

The variation of attention spans throughout a lecture is readily borne out by every individual's own experience regardless of their level of education: we typically lapse and seek alternate stimulation periodically, even if only briefly, through virtually any listening experience. This pattern and its effect on learning has been well-documented in many studies. For example, Johnstone and Percival[3] observed students in traditional lectures, recording breaks in student attention. In their study they identified a general pattern: after three to five minutes of initial "settling down", they found that:

"the next lapse of attention usually occurred some 10 to 18 minutes later, and as the lecture proceeded the attention span became shorter and often fell to three or four minutes towards the end of a standard lecture."

Other studies have generally confirmed this trend: there is a ramp-up period up to ten minutes in length, followed by cycles of attention and wandering of 15-20 minute periods.

While the correlation between attention paid and material retained seems obvious to most, the consequences are perhaps startling. Hartley and Davies' study[4] showed that students are not able, either psychologically or physiologically, to pay attention to the material nor to retain it throughout a traditional lecture. Their study showed that students could recall approximately 70% of the content from the first 10 minutes of the lecture but only 20% from the last 10 minutes.

In his book "Teaching Tips: Strategies, Research, and Theory for College and University Teachers", Wilber McKeachie enumerates several techniques that can be used to capture and maintain the students' attention, such as referring to material that is likely to be on tests, using changes in voice, facial expression, and movement, audiovisual aids, eye contact, and giving examples that are linked to student interests. Yet he concludes,

"all of these devices will help but recall the Hartley and Davies finding that students' attention tends to wane after ten minutes. A more radical device for maintaining attention requires breaking up the lecture rather than trying to hold attention for an hour or more."[5].

"Who Wants to Be a Mechanician" is an example of such a device, as it is played near the middle of a fifty minute lecture, which would be approximately at or just beyond the average time of the first major attention lapse after the "warm up" period.

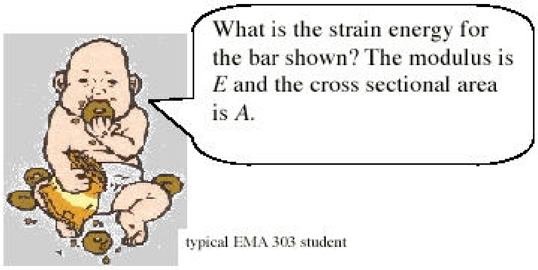
III. The Format of the Game

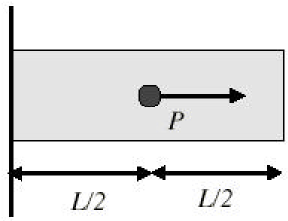
The game is conducted as follows:

- A bag or envelope with each student's names on a slip of paper is prepared. This is referred to as the "New" bag.
- Roughly in the middle of the fifty minute lecture, the lecture is brought to the first available natural pause, such as completion of an example or a topic.
- A student's name is drawn out of the bag and placed aside, into a second "Used" bag.
- The student is called up to the front of the room.
- A transparency with a multiple choice question is placed on the overhead projector. The question typically has four choices given. The question is usually based on the previous lecture.
- The student is then required to answer the question within a reasonable amount of time (usually two minutes). The student is encouraged to "think aloud" on the board..
- The student first tries to answer the question alone. Modest hints may be given by the instructor, and limited dialogue between the student and instructor may take place.
- If the student is stumped s/he can "ask the audience", whereby the audience votes but does not comment on which answer they prefer. The votes are recorded by the instructor on the blackboard. The student is then asked to provide their "FINAL ANSWER."
- If the student did not "ask the audience", then a poll is taken *after* the student has submitted their answer, to gage the class' response.
- The instructor briefly discusses each of the four choices, explaining why each was incorrect or correct. The question can then be used a springboard for further discussion.
- A student successfully answering the question alone is rewarded with 2 cookies; with audience help 1 cookie. Regardless of the outcome, the class is asked to applaud the student for their effort.
- In the next lecture, another student's name from the "New" bag is drawn, until all names have been called and placed in the "Used" bag. The names are then transferred back to the "New" bag and the game continues for another cycle.
- Each question (but not the answer) is posted on the course web site after it has been posed in class.

The total class time used for addressing one question is typically 5 minutes but can be more. The game was initially used for "Statics and Mechanics of Materials," a hybrid course for non-mechanics majors. The game has been subsequently used for "Mechanics of Materials," a core required course for Engineering Mechanics and Civil and Environmental Engineering majors. Four examples of questions posed in these classes, in the original slide format, are given below.

(1)

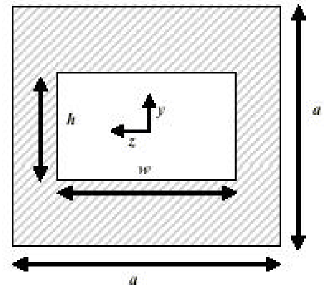




(a) $\dfrac{2P^2L}{EA}$ (b) $\dfrac{P^2L}{EA}$

(c) $\dfrac{P^2L}{2EA}$ (d) $\dfrac{P^2L}{4EA}$

(2)



The cross-section of a hollow beam is shown above. What is the moment of inertia for bending around the *z* axis?

Note: the respective moment of inertia of a rectangular cross section is:

$$I_z = \frac{(width)(height)^3}{12}$$

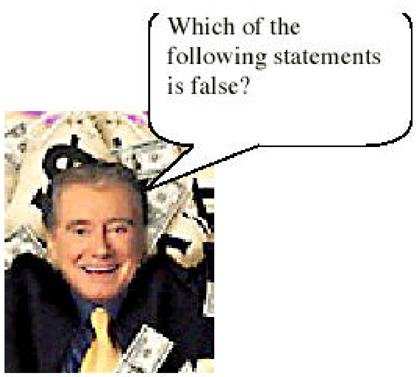
(a) $\dfrac{a^4}{12}$

(b) $\dfrac{a^4 + wh^3}{12}$

(c) $\dfrac{a^3 - wh^3}{12}$

(d) None of the above

(3)



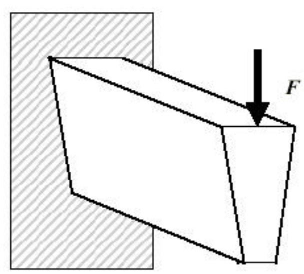
(a) Hooke's Law relates force and deformation.

(b) Strain is a dimensionless quantity.

(c) For any loading situation, the negative ratio of the lateral strain to the axial strain is equal to Poisson's ratio.

(d) The true stress is not necessarily the same as the engineering stress.

(4)



The cantilever beam shown above is fixed to a wall and a force *F* is applied at the outer end as shown.

Which of the following statements is true:

(a) The beam is in a state of pure bending

(b) The maximum bending stress occurs on the upper surface of the beam where the beam meets the wall.

(c) The maximum bending stress is compressive.

(d) None of the above

In the discussion of these examples, we shall resort to the language of mechanics in order to explain certain choices in the phrasing of the question and answers. As will be shown below, the choice of the *wrong* answers often turns out to be as important as the question itself.

In Example (1), the student is provided some comic relief and perhaps motivation by the imagery contained in the question. The relief is short-lived, though, as the answer can only be obtained if the student remembers the formula for the strain energy of a compound axially loaded member,

$$E = \sum_i P_i^2 L_i / 2 A_i E_i ,$$

and if the student also recognizes from equilibrium that the internal force is only non-zero and equal to P in the left half of the beam, whose length is $L/2$. If the student only gets as far as remembering the formula itself, wrong answers (a) and (b) can be ruled out as nonsensical since they are larger than the strain energy of an entire beam loaded with a force P. The student can perhaps get this far with judicious guessing, but the wrong answer (c) is specifically chosen as the result of the most predictable error - assuming that L is the length to use. The student therefore cannot blindly guess, but must think through the steps of the problem. A small bit of algebra on the board would likely be needed. Discussing the problem afterward allows one to clarify two concepts that are commonly misunderstood by students: the fact that the force P_i refers to the *internal* force, not an external load, and that the length L_i refers to the length over which that force acts, not the entire length of the beam.

In the Example (2), the student must understand how moments of inertia of simple structures can be combined to represent more complicated structures. S/he must realize that the hollow structure can simply be modeled as a pair superimposed beams with the inner beam assigned a negative moment of inertia. Even without understanding the combination of moments of inertia, (a) is easily ruled out since it represents the moment of inertia of a solid beam of the outer dimensions. However, with the realization of how to combine moments of inertia, the student can immediately rule out (a) and (b), and therefore might jump to answer (c) because of the tempting minus sign. Indeed, the student who was given this question did just that. But simply inspecting that answer reveals it is not dimensionally correct. The correct answer is (d). Notice how the nearly correct answer (c) extends the concepts covered beyond the combination of moments of inertia to also include the importance of dimensional homogeneity.

In Example (3), a range of concepts are covered, including the tantalizing prospect of exciting rewards for success. Finding the false statement requires very careful examination of the answers, since all seem at first to be correct to most students. The student can get to the right result in two manners. One way is by ruling in (a), (b), and (d) as clearly being true and accepting a lingering uncertainty regarding (c) since it seems true as well but is not quite as clear. The more direct approach results if the student realizes that Poisson's ratio is derived from an *axial* loading test, not for any loading situation. Many students fail to grasp this concept when first learning about Poisson's ratio, and this exercise allows that and three other basic mechanics concepts to be reinforced.

Finally, Example (4) is focused on bending stress concepts. If the student understands the sign of bending stresses and how their magnitude changes with cross-sectional area, then s/he will recognize that (c) is the correct response without having to think much about answers (a) and (b).

This is an example of a question that could be made more difficult. In any event, a discussion of why (a) and (b) are *wrong* allows the instructor to clarify the definition of pure bending, and to reinforce basic ideas arising with nonprismatic beams.

In summary, care is taken to ensure that the correct choice is not obvious, and as well, that the incorrect choices allow further review of more concepts.

IV. Results

The results of using the game are based on four classes in which the game has been used. In the Engineering Mechanics undergraduate program, it has been used in two semesters for “Statics and Mechanics of Materials,” where the class population was 20 (Fall 2002) and then 9 (Spring 2001) students, and in one semester for “Mechanics of Materials,” where the class population was 21 (Fall 2001). In these cases the students were either sophomores or juniors. The game has been adopted by a graduate student instructor who teaches a graduate-level Civil and Environmental Engineering course called “Advanced Concrete Materials.” The same game format was applied. In “Advanced Concrete Materials,” the class population was 8. All students were graduate students except for one senior undergraduate.

Each semester the game was used, some students exhibited a degree sheepishness and, in one or two individual cases, modest disdain in their initial reception to the game. These attitudes quickly evaporated after the first one or two games were played, as students appeared to realize that they were actually learning something from the experience, and as well, their number could be up next. In addition, a humorous and self-deprecating approach from the instructor tended to lighten the atmosphere and lead to further acceptance of the game in the classroom setting.

The most noticeable result in the classroom is the extraordinary level of attention given to the game. In most sessions of the game, the entire class is alert and following their peer’s predicament. The act of polling the audience further engages the class and gets many of them to think about the problem, although some will go along with their friends or neighbors, or the apparent majority. Those who never raise there hands are occasionally singled out for comment, to ensure that everyone ends up choosing an answer and not abstaining.

Another result from the game is an enhanced level of discussion in the classroom. The question itself is easily used as a springboard for further discussion, and routinely it generates questions from the students. This helps to establish a level of comfort in the classroom that starts to pay off in subsequent lectures, whereby students tend to pose questions independently of the game.

The effect on the instructor is also positive, mainly as it provides a break from lecturing and allows the instructor to relax. The typical time required to prepare each question is less than 10 minutes, and the preparation is often an enjoyable task compared with writing lecture notes, for example.

After the game is played, there is noticeable sense of rejuvenation in the class. Attention levels remain higher as the remaining part of the lecture proceeds. Certainly, after another 15 minutes or so, attention levels may wane again. Supplementing this approach with another active learning exercise can be rather effective, although the author has not explored this systematically.

Through the used of images included in the transparencies, phrasing of the question, and commentary from the instructor, a significant degree of humor and levity can be injected into the classroom, with the effect of further livening the atmosphere in the class. Nevertheless, there is a perceptible tension as a student struggles to answer the question. Undoubtedly, this tension contributes to the livened atmosphere in the class, as students in the audience imagine themselves in the same position shortly.

There is a risk associated with the game when it comes to students who possess a higher than average level of shyness, insecurity, or reservation. These students may tend to "freeze" and find the experience to be discouraging, alienating, and embarrassing. Furthermore, having the first contestant of the semester freeze into silence would not get the game off to a good start. The author has found that two techniques can help to address this. First, the instructor should secretly but deliberately choose more outgoing (but not necessarily the most bright) students as the first two or three "contestants" for the game. That way, the entire class will get to see examples of students surviving the experience. Second, the instructor can use hints and encouragement, including encouragement to "ask the audience" to a student who appears to be faltering. By following these guidelines, unjustified embarrassment of the students has been avoided.

The nature of the game allows common misconceptions to be addressed in class. There has been substantial research into methods that address common misconceptions in science education, and it has been found that interactive methods that get students talking are generally very effective at addressing this[6].

The game has so far been applied to class sizes between 9-21 students at an sophomore/junior level or a graduate level. It is believed that the game would also work well at an introductory level given its enjoyable nature. A concern though would be that younger students will more frequently lack confidence and feel intimidated by being thrust in front of their classmates. In addition, a difficulty with applying the technique to larger class sizes is that in a typical semester, not all students will have a chance to be called upon. A suggestion to address both of these concerns would be to call groups of 2 to 4 students up at once, and allow them to discuss out loud the possible answer to the question. This would allow more students to be "contestants" throughout the semester, and would lend support to less confident students through the presence of "teammates".

V. Evaluation

An e-mail survey was conducted after the second offering of the game in "Statics and Mechanics of Materials," after the semester had ended and the students had received their grade. This was done to allow the students to reflect on the entire course experience and outcomes in their responses. The response rate of the surveys was approximately 50%. The results from this questionnaire are as follows:

SCALE: 1=strongly agree, 2=agree, 3=disagree, 4=strongly disagree

1. The "Who wants to be a Mechanician" questions in class helped me learn the material: **1.3**

2. The "Who wants to be a Mechanician" questions helped me pay attention**: 1.3**

3. The "Who wants to be a Mechanician" questions were a silly waste of time: **3.5**

The following are representative comments that the students provided on these evaluations:

"The "Who wants to be a Mechanician" helped break the class up a little. It was nice to get away from just straight lecturing. It only made you pay attention more if you knew your name was still in the bag. It did help reinforce the material from the lecture before."

"It kept the class light-hearted and showed that you cared enough about the class to prepare it...I appreciated that."

"The most helpful part about the questions was that it helped me to pay attention in class sometimes when I was wandering. "

"The beauty of the "Who wants to be a Mechanician" question was that it put pressure on us to learn the material on schedule for fear of playing the village idiot in front of the village. I also learned a lot about what I didn't know (but thought I did). There were many questions that I thought I knew the answer to, but ended up being wrong. It was also an interesting break in lecture that brought many peoples attention back into focus. Everyone loves trivia."

"I think the 'Millionaire' questions probably would have had a better effect in a larger class setting. On the other hand, as a student, you had to attend regularly and keep track of the material being covered to have a chance at the questions." (from a student in the class of 9 students).

"You could try (maybe just once) dividing the class up into … groups to answer the questions where they could consult among their teammates to reach a...final answer."

Clearly, there was a high level of satisfaction amongst the students with the game. Interestingly, the attention-grabbing effect is explicitly mentioned in several of these comments. There is also a perceptible level of appreciation for the game, as evidenced in one of the comments above and also expressed verbally several times to the author. The game therefore has a positive effect on the character of the student-teacher relationship.

It is very difficult to assess what effect the game has had on learning and retention. One reason for this is the lack of any control group to test the effects of the game. In addition, the author, an assistant professor, only has one previous semester of teaching *without* using the game to compare with, and that was the author's first semester teaching a lecture course. While the author feels strongly that students exposed to the game exhibited better overall retention and understanding of the topics covered as compared to the students who were not exposed to the game, this judgement is of course subjective and may be due in part to other improvements in the author's initial teaching abilities.

Certainly, the student evaluations and comments do indicate that the students felt they learned something from the game. Furthermore, there is a clear increase in attention both during the game and afterward, as evidenced not only by the student evaluations but also by the obvious effects in the classroom as witnessed by the author and the other instructor who has used this method. If we are to believe any of the vast research associating attention levels with learning, then it is justified to feel optimistic that a significant improvement results from the use of this technique. It is interesting to note that in addition to the comments made by students indicating that the method indeed helped them learn, statistics collected of website usage showed increased traffic to the posted questions prior to examinations. The posted questions therefore serve as a resource that students see fit to spend study time reviewing.

A future strategy for evaluating the game in more detail would be to use a "control" by stopping the game for a few weeks and then testing whether the assimilation and retention were as good as when the game is used. Alternately, two sections with the same instructor could be compared by using the game in one section, and not the other. Results of such "controlled" studies will be published in the future. In addition, more detailed assessment through student interviews will be conducted in order to assess the effectiveness of the technique. Of particular interest are issues such as whether the availability of "wrong" answers does not cause inadvertent student mistakes.

Conclusion

The results observed by the author and relayed by the students show that the game has been a success. The author has continued to use it and encourages others to do so. The technique is not presented as a substitute for other active learning techniques, nor is it encouraged to be used as the only active or attention-grabbing technique in a lecture. However, on its own or in combination with other methods, the game enjoyable to prepare and execute, and is clearly effective at capturing attention, increasing student participation, enlivening the classroom atmosphere, and enhancing the relationship between students and instructor.

Invitation

The author invites comment and especially feedback from others who try this technique. The author is also happy to share further examples by request to: *<carpick@engr.wisc.edu>*

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Biographical Information

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