Asking Better Questions – Making Connections Through Developing Inquisitiveness

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"Could it be the questions tell us more than the answers ever do?" – Michael Card

Abstract:

The nature of engineering education tends to put students in a problem-solving environment. Given a particular challenge, the student becomes focused on obtaining a solution to some homework problem, exam question, lab experiment, design project or other task. Such exercises provide snapshots of what a student is studying, but they may not always encourage the student to think deeply about the subject matter. The purpose of the study presented in this paper is to provoke students to approach learning from a perspective of inquisitiveness so they can discover and define the problems to be solved.

The study conducted is based on a requirement for students to submit questions about course topics. The study was performed in two different courses during a single semester. The study has several significant outcomes. The first is a picture of the student learning process as they progress from initial curiosity to wrestling with specific topics to an understanding that allows them to make connections to the course topics. The second outcome develops a picture of how students change in their ability to pose insightful questions as they obtain practice in doing so. The third outcome examines the relationship between the study presented and traditional engineering pedagogy.

Introduction

Engineering students are trained to solve problems. College prepares them with the technical expertise to numerically solve a variety of problems in a systematic manner. This process presents students with well-defined problems. As a result, students develop the ability to answer questions and solve problems. However, they have little reason to ask the questions that define a problem from the circumstances encountered in the engineering workplace. The problems that engineers face are best framed by asking questions that connect the workplace situation with engineering skills and techniques. How can we produce within students the motivation to ask questions to gain understanding and insight when faced with new challenges? This is the question that perhaps lies at the heart of the case study presented here.

Traditional engineering education is heavily invested in training students to solve problems that are posed complete and self-contained. An unintended outcome of this pedagogy is that students begin to rely heavily upon the assurance that the problem has all of the necessary information. When these students enter the workplace, problems no longer define themselves. Definition of the problem or problems becomes, perhaps the most important component of the engineering solution. Can we train students to ask the necessary questions that will lead to the framing of a problem in a format such that the student can use their technical expertise to solve the problem?

The goal of the study described in this paper is to stimulate the thinking of engineering students about the circumstances and questions that surround a specific engineering situation. The hope is that this ability will benefit students by helping them develop a sense of curiosity and wonder that allows them to think beyond the bounds of a textbook. The study also gives an opportunity for a faculty member to examine student thought processes from a different perspective. While not the initial goal of the study, the true value of the study may be to give the faculty member a better understanding of how students understand different course topics.

The following sections outline the study and its outcomes. The first section defines the methods used. This includes both implementation and the criteria upon which the assessment is based. The next section provides an assessment of the results. The final section provides a reflection on the results and some of the possible implications for how engineering courses are presented and received.

Methods and Requirements

This section describes the methods used in the study. This includes both the presentation of the study to the students and the methods used to assess the student submissions. These are discussed in separate subsections below.

Methods – Student Requirements

This study was implemented in 2 different courses: *Engineering Materials* and *Mechanisms and Machines*. Two faculty members were involved in the study. As a result of having multiple courses taught by different faculty, the methods used had some variation as dictated by course structure and faculty teaching style. In this paper, the focus is on the general approach and results to show the effectiveness of the premise. Detailed methods or results will be presented as necessary to demonstrate specific outcomes.

The primary requirement of the study in each of the courses was to have students submit some minimum number of questions related to course topics. In one course, students were required to submit two questions every three weeks. In another course, students were required to submit one question for each chapter covered. In all cases, students submitted approximately ten questions at relatively evenly spaced increments throughout the semester. Motivation was provided by including the question submission requirement as part of the course grade.

The questions submitted by students were to be related to the course topics. Students were actively encouraged to submit questions that would expand their understanding of the course material beyond the standard lecture and textbook presentation. The goal was to push students beyond the course material to develop a sense of inquisitiveness about their understanding of topics and the application of these topics to various problems. This goal is reflected in the evaluation of the student questions as described in the next subsection.

Methods – Assessing Student Submissions

In both courses, the faculty agreed to evaluate student submissions on a four point scale. The low end of the scale, 1&2, were considered to be relatively simple questions. These were questions directly related to the course material that could typically be answered by review of the course text or notes. Questions at the upper end of the scale, 3&4, were questions that demonstrated understanding of the course material and expressed interest in additional, related information that was not expressed in the course text or notes.

The four point scale allowed the submissions to be looked at from several different perspectives. The methods that produced the most easily interpreted data included looking at the quantity of questions in each category and looking at the numerical averages of the questions submitted. These results are presented in the next section.

Results

The different course formats involved in the study suggested different possibilities for the analysis of the questions submitted. This section describes the evaluation methods and some possible interpretations.

One of the courses, *Mechanisms and Machines*, involved in the study was taught in a modular format. The course contained 4 modules, each of approximately 3 weeks duration.

Questions were submitted on a regular basis with an average of 21 questions per week being submitted by the class. The questions were grouped into two “super categories.” “Simple” questions were defined as those from the lower end (1&2) of the 4 point scale while “thoughtful questions were defined as those from the upper end (3&4) of the scale. The percentage of questions in each of these two “super categories” is plotted by week and the result is shown in Figure 1. Note that the numbers for each week in Figure 2 will always add to 100%. The questions are plotted on a percentage basis to make the results independent of the total number of questions asked in any given week.

The most interesting result shown in Figure 1 is the correspondence of the “simple” and “thoughtful” peaks with the modular progression of the course. For every module, the “thoughtful” questions peak just following the last week of the module (weeks 5, 8, 11, 14) while the “simple” questions peak just prior to the end of each module.

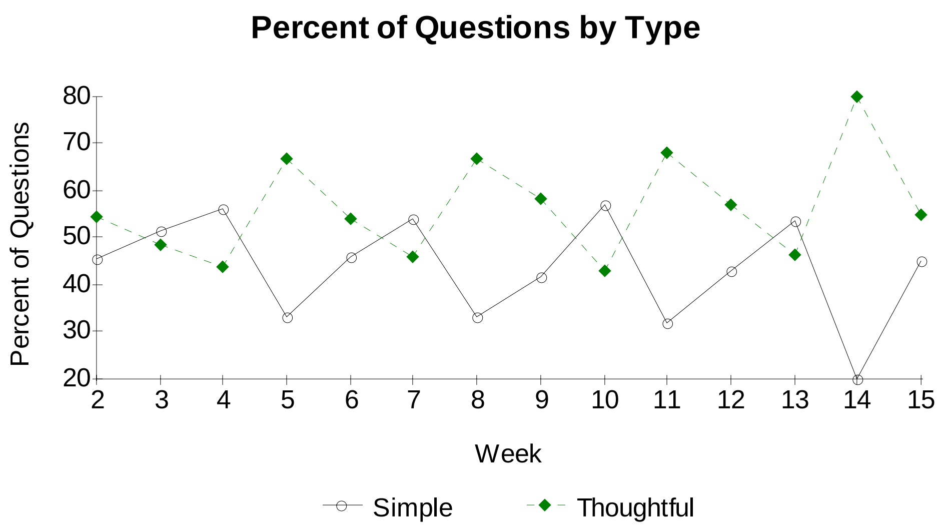

Figure 1: Percent of Questions Submitted Each Week by Type

The pattern shown in Fig. 1 seems to imply a cycle of learning where students are wrestling with understanding concepts (“simple” questions) followed by a cycle of “understanding” where the students want to extend the concepts learned to topics beyond the given text and notes (“thoughtful” questions). This seems to reflect a natural learning cycle, though it also presents the challenge of how to encourage students to be more reflective and thoughtful in their basic learning. This will be considered in the final section.

A second course in which questions were collected was the *Engineering Materials* course. The objectives in this course focus on building, through the entire semester, an understanding of the phenomena that control properties in materials and the application of materials in engineering design. This stands in contrast to courses designed to teach specific analytical skills and techniques. Questions submitted were used in class discussion, with insightful questions providing examples, while simple questions were addressed as part of the basic presentation. In contrast to the *Mechanisms and Machines* course, the questions for the *Engineering Materials* course were evaluated by averaging the questions relative to the four-point scale. The average rating of questions submitted for each chapter through the semester is presented in Figure 2.

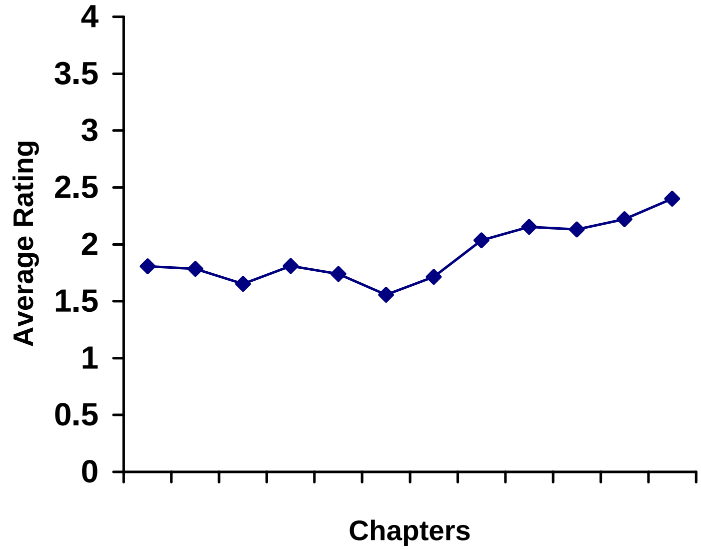

Figure 2: Average Rating of Questions vs. Chapters Through the Semester

This result indicates a relatively steady pattern of simple responses for the first half of the semester, followed by a trend of increasingly insightful thinking during the second half of the semester. Early student response to this exercise could suggest a lack of familiarity with this idea, or a desire to "complete the assignment." Both of these explanations are consistent with the premise that students are preoccupied with fulfilling the demands of the instructor, i.e. answering questions, rather than understanding the problem through recognizing relevant questions. The steady trend toward better questions during the last half could represent the increasing credibility of the exercise, as well as practice at thinking about the subject and formulating questions.

Reflections

The study presented has focused on developing the ability of students to broaden their thinking through their posing of insightful questions related to course material. In spite of the different course environments considered, the results reveal several common threads for future consideration. These include an apparent increase in the student ability to reflect and ask thoughtful questions as they become familiar with the material, and an increase in overall ability to frame good questions.

While somewhat different, these outcomes perhaps both address the challenge of how to increase the ability of students to reflect upon information within the learning process. How much do students have to know before they are capable of pursuing higher knowledge on their own, and can practice in reflecting upon material (asking questions) enable them to do more reflection with less information? Should the engineering education process be one of “feeding” students information until they achieve a basic competency, or would it be better to strive to achieve competency through reflective learning? If students gain practice in posing questions in a number of classes, will that improve their overall learning experience and enable them to define and assimilate new material easier? These are perhaps the biggest questions posed by the study. Future work will try to provide some degree of resolution for these questions.