

# Using Case Studies to Bring Real World Situations into the Engineering Course Learning Environment

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**Abstract** – This paper presents observations from applying the principles of the case study method of teaching to a senior level applied engineering course. Its purpose is to provide an example application in a course that was composed strictly of a series of case studies. Students studied four different situations that are typical of projects done by a consulting or plant engineer in industry. Each case was presented during an initial information class meeting and the students worked on the analysis and design necessary to complete the assignment over a period of several weeks. Students were requested to write their results in the form of a report that mimics one that would be completed for a consulting firm's client. A follow-up survey taken at the end of the semester indicated that they enjoyed the course more and felt a greater connection between the cases studied and real situations that they will encounter in a professional job. The students also recognized other lessons learned from the course structure helped them to be more efficient with their time, to communicate their results effectively in a professional style, and to recognize the need to avoid the pitfall of procrastination.

*Keywords:* Case studies, pedagogy, projects

## **MOTIVATION – WHY IS THIS IMPORTANT?**

Educators in engineering schools should continually be looking for ways to improve the relevancy of their courses as they pertain to the students' needs. Those needs should focus on the kind of professional activity the students will have in the future. This in turn will vary according to student population, their program, and their course of study. For some courses or schools, a large number of the students may go on to graduate school and thus the course focus should include opportunities for higher-level analytical studies than normally expected for a typical undergraduate course. It is, however, a general truth that the majority of undergraduate engineers will go on to jobs in industry or technically related fields in business. In these positions, their activities will be applications, not research or analytically, oriented. Thus, one primary goal of an undergraduate engineering program should be to provide a student the tools necessary to succeed in this type of environment.

The tools necessary for success go beyond the understanding of core engineering principles but should also include insight into the thought processes of practicing engineers. The tools will include learning how to work within time, financial, physical and other practical or intangible constraints that exist in professional job situations; and finally learning how to effectively communicate their results. Any undergraduate engineering curriculum should serve as a bridge between their initial period with a "student mindset" and the operating practices of engineers in professional positions. The case study method, discussed in more detail later, is one pedagogical tool that provides this bridge.

Engineering curricula generally follow the engineering science model in practice for the past fifty years or so [5], with recent modifications to include a project-based approach. A capstone design project is a key part of the senior year [2] as is perhaps a cornerstone design project in the freshman year [3]. These are focused on improving the design thinking of engineering students through the use of project-based learning. Depending on the instructor preference, other courses may include individual design or analysis problems or projects to supplement the course

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learning objectives. Dym, et. al. [4] recently provided a good summary of the project-based approach in engineering education.

Previous sessions of ASEE conferences have included papers on the use of case studies in engineering instruction. This paper is intended to further the implementation of the case study method with several specific objectives in mind. One of which is to describe implementation of the case study method not as a cornerstone or capstone project, but as the basis for an entire higher-level course oriented toward a specific engineering topic. This paper will also serve as another example to motivate other instructors to try this approach. A final objective of the paper is to relate several lessons learned during a trial implementation where case studies were the primary instructional format. Therefore, this paper describes a “work-in-progress” with implementing the case study method that will help identify topics for further study.

The subject course for this trial implementation of case studies had two main teaching objectives. The first was to help teach applications of specific technical subject matter learned in a previous course. Secondly, it also provided experience in addressing technical problems not from the perspective of a student but that of a practicing engineer.

### **ADAPTING THE CASE STUDY CONCEPT SUCCESSFULLY USED IN OTHER DISCIPLINES**

The case study method was originally implemented at the Harvard Business School in the early twentieth century and is now universally accepted as a primary pedagogy within business schools [6]. The method is applied to problems ranging from simple situations to complex, open-ended ones that require a great deal of concept synthesis. A business school case study is generally organized in the following manner. First, the case presents background information that helps introduce the concepts, technologies, financial factors, and people involved in a real or fictional corporation or organization. The case then presents a problem, incident or current challenge that exists; with the student being asked to propose a solution that is appropriate for the business context of the situation.

Russ and Nance [8] applied the case study method to teach an interdisciplinary mixture of engineering economics and business policy and reported successful results in terms of both student enjoyment and their perceived learning value. Some reference and continuing education materials used by practicing engineers after graduation use a variation of the case study approach to provide practical ways to review an engineering topic. For example, the author was a chapter contributor of one case application in a recently published reference book that was a compilation of heat transfer problems taken from various practical experiences [7].

One key benefit seen in the case study method, as applied in business school context, is that the student is presented with situations that are purposely left more open-ended. Students must synthesize knowledge learned in their courses and apply to real-life business situations. When applied to an undergraduate engineering course for this trial course implementation, the case studies had similarities to a project in a typical engineering course. The main difference being that the case studies were presented as more open-ended questions to be approached from the perspective that a consulting engineer might face if asked to help solve a problem at a client’s facility. In this sense, the case studies were also similar to the objectives as presented in a senior year capstone or freshman year cornerstone engineering design project.

Case studies can be applied in either a design-oriented course, for example in an upper-division course on a specialized engineering topic, or as part of a core engineering science course such as heat and mass transfer. The premise put forth is that, even within fundamental engineering courses, enhanced learning and overall improvement in student involvement might be achieved by structuring the course to include case study applications.

### **RESULTS OF AN INITIAL TRIAL IMPLEMENTATION**

A recent refocusing and redesign of courses in the University of Georgia engineering program that deal with building environmental control offered the opportunity to apply the case study approach. Two existing and topically related courses were redesigned to be a sequential series, with the first course covering the equipment, systems and analysis techniques needed to analyze buildings and their heating, ventilation and air-conditioning (HVAC) systems. The second course was to be applications oriented and designed around the use of case study projects. The objectives for this second course were to build upon the information learned in the first course, for example learning the relevant thermal and fluid processes, and successfully applying these to more open-ended

problems. The modules also provided a more in-depth experience with computer software packages that are used by practicing engineers in industry and consulting positions. Secondary objectives included exposing the students to the process that a consulting engineer might go through when asked to help evaluate a problem situation and provide recommendations for a solution.

The subject course was divided into four case study modules that were derived from practical situations with local stakeholders. The first course offering was during the fall semester of 2005. The first module had students analyze the predicted heating and cooling utility bills for a simple residential house. The case was based on a recent “green” house that the Athens-Clarke County (Georgia) Habitat for Humanity built that was designed to have higher energy efficiency and lower environmental impact than their typical house. Habitat for Humanity was interested to know the expected energy cost savings that resulted from higher insulation and other building design and material changes that were made to determine if this was a good strategy for future houses. Thus, this case offered the class an opportunity to perform a small community service as well as gain more experience in energy modeling. Modeling was done using a public domain software package called eQUEST [1] that is commonly used at engineering firms. This simulation package combines a graphic front-end with the U.S. Department of Energy building energy model appropriately called “DOE-2.2”, which is currently the most commonly accepted tool for conducting building energy simulations in industry.

A second module had the students analyze the HVAC air distribution patterns within their classroom using a popular computational fluid dynamics package called AirPak from Fluent, Inc. This module was primarily used to train the students on how to use this software package for the third module, since it was not available for use during the first semester course.

The third module had the students study a ventilation exhaust hood at a local manufacturing facility that was performing poorly. The hood is installed above the cutting line of a fiberglass insulation manufacturing plant and was not effective at capturing free-floating fiberglass particles from the cutting process. The students visited the site and witnessed the problem first-hand. They used AirPak and other air pressure drop analyses to estimate the actual air flow rate and spatial distribution at the hood inlet, and compared that to the flow velocities that would be expected to provide better capture. The students then developed and analyzed their own design modification that would improve the system performance. The students were asked to consider issues in their proposed design, such as the cost and ease of implementing the modifications at the plant.

The final case study module had the students analyze the heating and cooling load and ventilation requirements for a small (7,000 ft<sup>2</sup>) building being gutted and renovated on campus, and then to design an HVAC system to serve the building needs. They were presented with the project description and building layout drawings. After a visit to the site, they designed a system within the limitations of the campus utilities, setting and building layout.

As each new module began, a class session was held where the background and objectives for each module were explained. Site visits were made to let the students see first-hand the situation being analyzed. Since the course focused on case studies and the student’s independent work as the chief learning tool, a limited number of additional class lectures were necessary. As the students progressed on each module, the regularly scheduled class sessions were devoted as work periods. These sessions gave the chance for individualized instruction and assistance or to provide demonstrations on using the software. Occasionally, class sessions were used to conduct a group discussion on the key issues they were experiencing with a module.

Each case study was completed over a three to four week period. The students were required to provide an intermediate reporting of their progress and a final report. The students were told to prepare their reports as if they were delivering them to the stakeholders involved. The final report format was to simulate that which might be prepared by a consulting engineering firm, with the problem and solution summarized clearly and concisely. This addressed the secondary objective for this course of providing an experience similar to what a practicing engineer would go through in industry. Course grading was solely on the intermediate and final reports, with the relative weighting for each module made based on the complexity of the analysis required.

In summary, the traditional course structure of lectures combined with homework problem assignments, labs, and exams was replaced by focused study case modules that directly related to real situations that the students could expect to address in a professional job.

### **Students in this Program**

Many of the students in this engineering program also work part-time at technically related jobs. Thus, they are already being potentially exposed to practical applications of their coursework. Three of the students work at the same industrial plant where the exhaust hood of case module three is located. They therefore had a very real appreciation for that particular case study subject. For all but two students in this course, the area of HVAC was not their primary technical area of interest for future employment. The secondary objectives of exposing students to practical problem solving techniques by practicing engineers were therefore just as important as the specific technical skills learned.

### Survey Description

A survey was given to all 12 students in the course to gauge the initial success of this method and identify problem issues. All 12 students responded to the survey. It is recognized that this is a small sample size (12) to be used in making statistical comparisons. It did, however, use the entire population of students registered in the course and therefore can provide some indication of the positive or negative aspects of this trial implementation. The survey consisted of seven questions asking for numerical evaluation of the course. A few other open-ended questions concerning suggestions for types of projects in the future were asked but are not discussed here. The survey questions are listed in Table 1.

**Table 1 – Student Feedback Survey Questions**

<u>Question #</u>	<u>Question asked</u>
1	Compared to other engineering courses, I like the format and organization for this course
2	More class meetings should be scheduled
3	The workload has been too heavy for this course
4	I prefer a more traditional structured course with lectures, homework, etc.
5	Ample opportunity exists to ask questions on doing the projects
6	I learn more from the traditional engineering course format compared to doing case studies like in this course
7	I felt disengaged from the course this semester due to lack of class meetings

### Survey Results

Question 1 - The first question was intended to see if the students were able to adjust out of their conventional norm for courses and if they actually liked the course. Results for this question are summarized in Figure 1.

Question 2 - The next question asked about the number of class meetings. The case study method can just as well be applied in courses that meet every regularly scheduled time. However, a secondary goal of this course structure is to help the students' transition to the professional job mindset and become more responsible for keeping their progress in this course balanced with other courses (as well as job and/or family life as appropriate). Results for this question are summarized in Figure 2.

Question 3 - The third question asked students to comment on the overall workload for this course by asking, "The workload has been too heavy for this course". Generally, students are honest about their time spent on a course and this question was intended to gauge whether the different course structure resulted in an increased time burden. Results for this question are summarized in Figure 3.

Question 4 - The fourth question was intended to help reinforce, in an inverse way, any conclusions derived from the first question, but by giving a more specific comparison with a traditional course format. Results for this question are summarized in Figure 4.

Question 5 - The next question asked for student feedback to the statement, "Ample opportunity exists to ask questions on doing the projects." One of the dangers with the revised structure used in this course (of not meeting every scheduled class period) would be to unintentionally restrict the student's ability to ask questions and get help as needed. Results for this question are summarized in Figure 5.

Question 6 - The question states, "I learn more from the traditional engineering course format compared to doing case studies like in this course" and focuses on the student's perception of learning the topic material or skills in the format of this course compared to traditional courses. Results for this question are summarized in Figure 6.

Question 7 - The final question tries to gauge if not meeting every regular scheduled class meeting made it difficult for the students to stay engaged with the course. Results for this question are summarized in Figure 7.

### ANALYSIS OF SURVEY RESULTS

The survey results confirmed the initial impression from the mid-term survey that overall, the students liked the case study format, as shown with question one and corroborated from the answers given to question four, although the feeling was not universal. The students were more neutral to the question gauging whether their perceived learning was enhanced by using the case study approach (question six). One-third of the class was neutral on this issue, but over half the class did either disagree or strongly disagree that the traditional format is a better learning method.

The other questions were designed to gauge if changes should be made in the instructional implementation for future course offerings. During the semester, the students were told to use the class time between regularly scheduled meetings to work on their projects. About two-thirds of the class took this opportunity to regularly work on their projects with the instructor available to address specific individual questions. This is more representative of the working environment they will experience in their professional careers after graduation. Questions two and five provided positive feedback that the students did not feel handicapped with the way this course was implemented. Question three (“workload too heavy”) was also used to determine if the change in course format was perceived as also making a heavier workload for the students; the results indicate this was not the case. One concern at the start of the semester about the students feeling disengaged from the course was shown to not be a problem, based on the results from question seven.

The survey results were analyzed to check if the conclusions discussed above are statistically different from the “neutral” answer (three). Assuming the results to be from a normally-distributed population, the analysis involved applying a two-tailed test of the hypothesis that the mean result for each question did not differ from a neutral answer of three. The test computed the actual standard normal variable,  $z'$ , using the equation (1)

$$z' = \left| \frac{\bar{x} - \mu}{\sigma/n} \right| \quad (1)$$

where:

$\bar{x}$  is the neutral answer (3.0)

$\mu$  is the survey question mean response

$\sigma$  is the survey question response standard deviation

$n$  is the number of responses (12)

The actual standard normal variable,  $z'$ , is compared to the normal probability distribution variable,  $z$ , to determine the significance level. For example, if the value of  $z'$  is greater than 1.96, the survey result would be considered statistically significant at the 95% level. Table 2 summarizes the statistical analysis results, which concludes that all results can be considered significant at a confidence level greater than 95%. Thus, even though the class size was relatively small, the conclusions made from this analysis can be taken as a positive reinforcement of the survey results and method.

**Table 2 – Summary of Survey Results Statistical Analysis**

Question #	Response mean value, $\mu$	Standard deviation, $\sigma$	$z'$
1	1.92	0.48	27.0
2	3.25	0.67	4.5
3	3.42	0.64	7.8
4	3.75	0.98	9.2
5	1.83	0.64	21.8
6	3.58	0.66	10.7
7	3.75	0.64	14.0

In addition to the numerically rated questions, several open-ended questions asked for advantages and disadvantages of the course as well as suggestions for future course improvements. Answers to these questions corroborated results of the numerically scored questions. Tables 3 and 4 summarize student comments on what they perceive as the advantages and disadvantages of this course format, respectively.

**Table 3 – Summary of Student Perceived Advantages of Course Format**

<u>General Response Synopsis</u>	<u># of similar responses</u>
Allows for better identification of course topics to real world situations similar to future jobs	6
Easier to integrate into their personal schedule	3
Enjoyed the "out of box" learning experience	1
Forces students to think for themselves in analyzing projects, which should lead to better long term learning of topic	2

**Table 4 – Summary of Student Perceived Disadvantages of Course Format**

<u>General Response Synopsis</u>	<u># of similar responses</u>
Not enough time to get to learn the full extent and application of the software packages used	2
Students can get in a time crunch if they procrastinate on the projects	2
Timing of when case study results are due, especially at end of the semester	1
More in-class discussion and instruction on the case topic and special topics for this case as the case is introduced	1
No perceived disadvantages	5

It is important to point out that no objective evidence was gathered that this course format was better in teaching engineering skills in the narrower context of technical knowledge. The objectives of this course implementation were broader than that. In the broader context of skills a student will need to have in order to successfully practice engineering in a professional job, over one-half of the students responded positively. They stated that they gained a better identification of the course topics as applied to real life situations and how to analyze a project in the broader context of other constraints. Therefore, the conclusion is that, in general, the objectives for this course were met and work should continue to refine this course for the next offering.

### **COMMENTS AND RECOMMENDATIONS FOR FURTHER TEST AND IMPLEMENTATION**

Results of the case study analyses were supplied by the instructor to the stakeholders for modules one, three and four. (The second module was mostly practice in using the computational fluid dynamics program.) The local Habitat for Humanity affiliate was appreciative of the information that the annual utility cost savings for heating and

cooling would be \$50 for their higher efficiency design, which can be a significant amount for low-income homeowners. The “best” redesign suggestion for the exhaust hood (module three) was presented to the plant engineers by the instructor during a later meeting. The “best” design was chosen by the students and instructor during the final class session of this module. The main result useful for the university physical plant engineering staff for module four (the small building being renovated on campus) was a confirmation of the peak design cooling load for this building. The university staff had questioned the values presented by a potential mechanical contractor and the energy modeling results from this module confirmed their own estimates. Ideally, the results would be presented by the students themselves to the stakeholders, but the logistics did not allow that approach to be used in this course.

The initial test of this method applied key aspects of the business school case study method, as adapted for an undergraduate engineering course. The problems solved were taken from actual issues or situations identified from contacts within local industries, organizations and the university. The case modules were introduced to the students from the perspective of their acting as an outside “consulting engineer”, with constraints that actually exist in each situation. The difference between this test application and that for a business school is that the students were given more focused analyses to conduct than a more open-ended business school case study. For example, in the third module (the exhaust hood), the students were asked to focus on the hood design itself and how a redesigned hood might fit within that location of the existing plant. They did not address other issues that affect the hood operation, such as the fact that this hood ties into an existing plant exhaust system and its associated limitations, the cost/benefit to the plant or other operational issues.

Several key observations were made as part of the preparation and delivery of this course. This approach is best suited if the instructor has a good working knowledge of problems as they exist in industry or other potential sources of case studies such as the university physical plant. This includes insight into the behind-the-scene reasons or constraints as to why a particular design or process is the way it is. The instructor should develop a working relationship with local industries, commercial locations and the university physical plant staff. Taking tours of facilities and studying how they operate will help identify potential problems that can then be developed into case study modules. A field trip to the site by the students to actually see the situation first-hand is recommended if possible. The instructor will likely also benefit by learning more about the process operations studied in each case module.

There is no reason the case study method could not be applied to any level of undergraduate engineering course within any discipline of engineering. The types of problems and depth into which the problem is studied may be different for a lower-division course (for example Thermodynamics) compared to a senior-level course in say Energy Systems Engineering, but the concept is still the same. A higher-level course that is more applications oriented does simplify the effort required to integrate case studies. What is vital in any case is a desire to consider this approach by thinking outside the box of a traditional course structure.

Students too must be receptive to a course structure that is a little different from what they are used to. Some like to stick with a familiar routine within a course, but based on the results of this initial test application it appears that students are indeed open to the case study approach.

The author is interested in hearing from others who may have attempted courses that use a variation on this approach, particularly where the entire course consisted of case study applications. Contact the author via email at [lawrence@engr.uga.edu](mailto:lawrence@engr.uga.edu). One suggestion is to establish a clearinghouse to compile examples of case studies that could be shared among instructors at various institutions.

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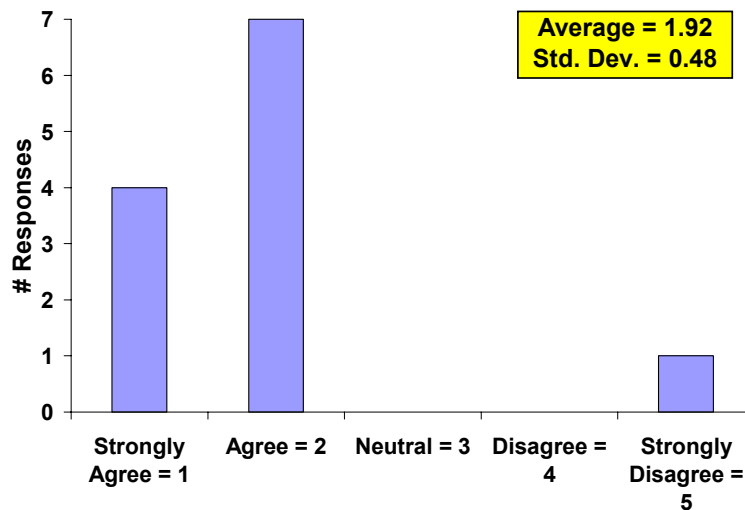


Figure 1 - Survey Results for Question 1, "I Like the Format"



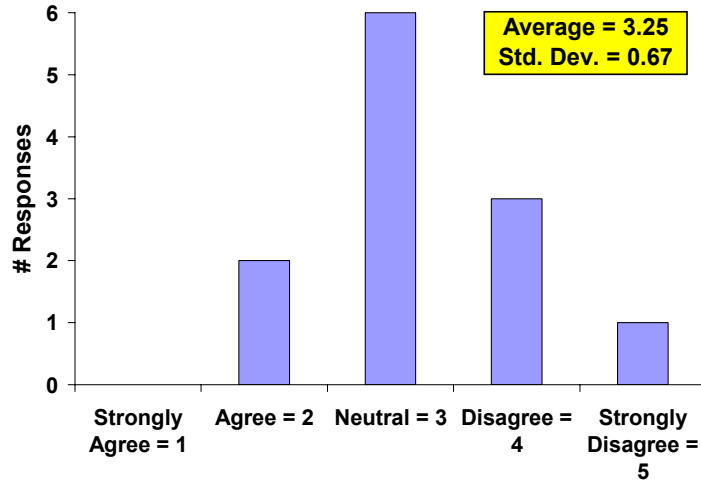


Figure 2 - Survey Results for Question 2, "More Class Meetings Needed"

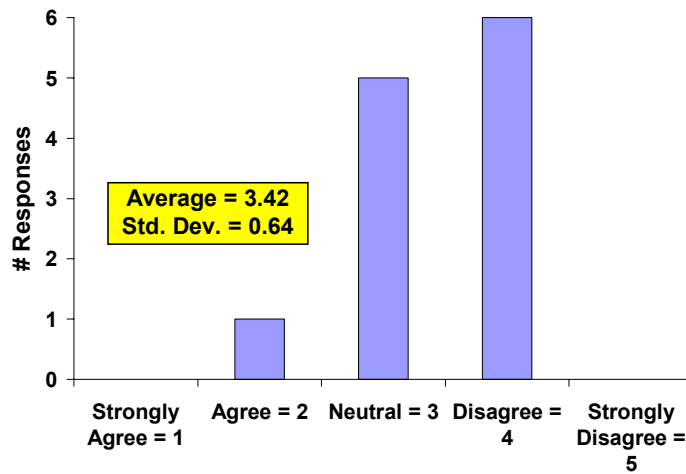


Figure 3 - Survey Results for Question 3, "Workload too Heavy"

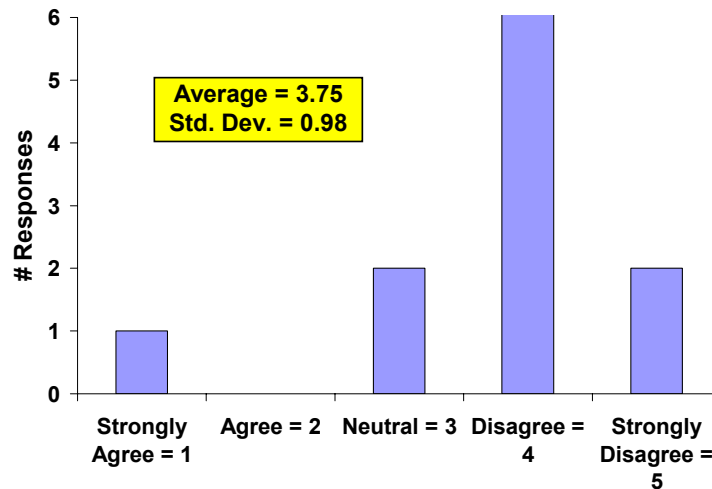


Figure 4 - Survey Results for Question 4, "I Prefer a More Traditional Course"

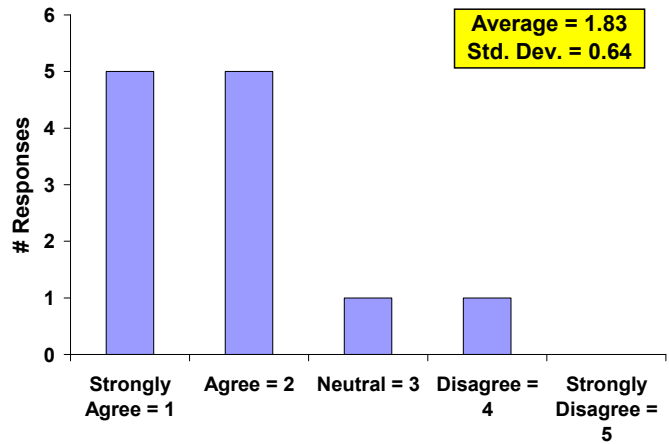


Figure 5 - Survey Results for Question 5, “Ample Opportunity Exists for Questions”

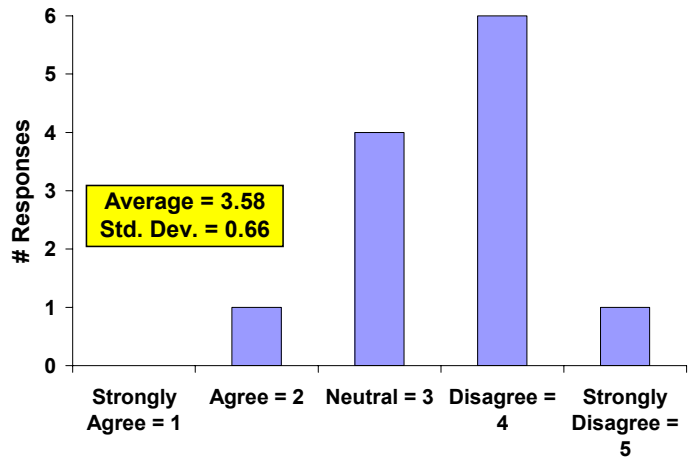


Figure 6 - Survey Results for Question 6, “I Learn More in Traditional Course Formats”

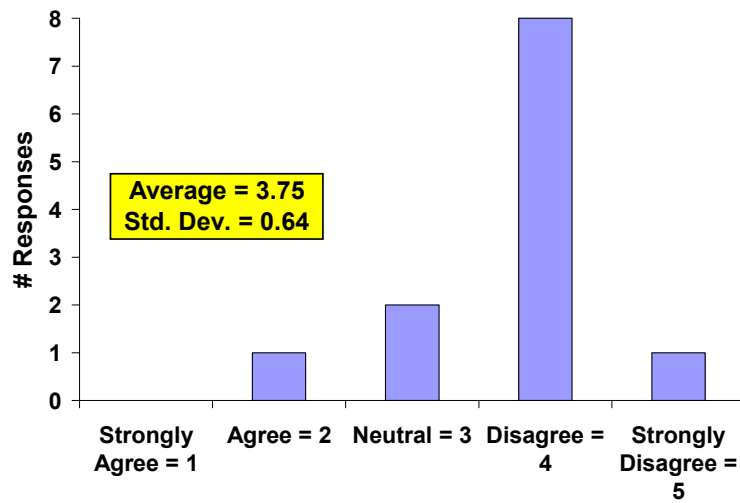


Figure 7 - Survey Results for Question 7, “I Felt Disengaged from the Course”

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Dr. Lawrence is a member of the Faculty of Engineering in the Department of Biological and Agricultural Engineering at the University of Georgia. Before earning his Ph.D. and entering an academic career, Dr. Lawrence spent approximately 20 years in engineering and management positions in industry and consulting. He earned his bachelor's degree in Environmental Science from Purdue in 1978 (*summa cum laude*), a M.S. in Mechanical Engineering from Oregon State in 1982, a second M.S. in Engineering Management from Washington University in St. Louis in 1989 and his Ph.D. in Mechanical Engineering from Purdue in 2004. His primary technical interests are in sustainable buildings ("green buildings") and industrial processes. He is currently is vice-chair of ASHRAE technical committee TC 2.8, "Buildings Impact on the Environment and Sustainability".