



Case-Based Instruction for Innovation Education in Engineering and Technology

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Abstract

The need for the integration of relevant curriculum focused on innovation theory and the management of innovation within engineering education has been a topic of ongoing discussion at the national level. The Council of Competitiveness suggests STEM graduates will be the key to innovation growth, although the number of engineers entering the field is not sufficient to replace retiring professionals. Today's global economy requires engineers and technologists to take the lead role in innovation and idea generation, although innovation is not a topic that is typically included in the undergraduate curriculum.

One approach to teaching innovation theory is case-based instruction. Case studies are effective in engineering education because they bridge the gap between theory and practice. Students also report being more engaged in coursework when case studies are included in the curriculum. Although effective, case analysis is not as prevalent in the classroom as the more traditional lecture-based instructional methods.

This paper explores student attitude toward the use of case studies in engineering education. The data is drawn from the results of a mixed-methods study of engineering technology students who participated in a case study analysis of disruptive innovation theory. An assessment of student attitude toward the use of the innovation case study was given to a sample of 90 engineering technology students. Qualitative results from this instrument were derived from a directed content analysis research methodology.

This research is intended to provide insight into student perception and acceptance of the use of cases in the engineering and technology classroom. This study examines students' personal views of their attitudes through qualitative content analysis. Research will be supported by thick, rich description drawn from students' own words to gain further insight into student perception of both innovation education and case-based instruction.

Need for innovation education

Traditional engineering curriculum creates people who are efficient researchers and highly productive, but this approach does not encourage creativity or innovation^[1]. Innovation can be defined as a new and valued product, process, or concept that has been introduced to the market or society^[2]. Engineering educators should better prepare students for careers in innovation. In doing this, they must "undermine their students' blind commitment to the engineering paradigm"^[3] which is centered around the scientific approach to knowledge making. To accomplish this challenge, the exploration of paradigms such as ones used in the schools of business, communications, and political science is suggested. Incorporating this exploration will allow the engineering and technology student to critically reflect on and debate the beliefs, practices, and values of their paradigms and introduce them to a range of choices to evaluate information with a more situational and pragmatic approach to problem solving^[1, 3]. Steiner suggested this can be accomplished by building upon deep domain knowledge to introduce curriculum focused on the development of non-technical skills and attitudes.

Case-based instruction in engineering and technology education

The use of case studies can be an effective tool for teaching innovation theory. Case-based instruction has been used widely to assist students in bridging the gap between theory and practice since the material is presented to the student in context^[4]. The case-based instructional method is a pedagogical tool that shifts the emphasis from a professor-centered to a student-centered environment^[5]. Case-based instruction has frequently been used in the professional fields of medicine, law, and business because it creates contextualized learning environments^[6] which helps to bridge theory and practice in a controlled academic environment^[4].

Engineering and technology students have not traditionally been exposed to case studies in their undergraduate studies^[7]. Case-based instruction in engineering allows the student to engage in the curriculum by adding a sense of realism to the content^[8]. The “case” for case studies is so compelling, that the National Academy of Engineering formulated the following recommendation: “Engineering educators should introduce interdisciplinary learning in the undergraduate curriculum and explore the use of case studies of engineering successes and failures as a learning tool”^[9].

A recent study analyzing the connection between higher education practice and the development of innovation-related competencies in recent graduates identified four categories associated with workplace innovation. Opportunity identification, idea (or solution) generation, the ability to question ideas, and the ability to lead others were the shown to be the most desired competencies to drive business innovation^[10]. Vila, Perez, & Morillas (2012) found more active, student-centered methods of teaching and learning were most effective in developing the competencies required to innovate in the workplace. Contextual learning environments such as work-based learning, internships, case-based learning, and project-based learning were found to be the most effective classroom practice for developing innovation competencies with undergraduate students^[10].

Case-based instruction for innovation theory

Lecture-based instructional methods often leave students unengaged, uninspired,^[11] and can present topics without applying contextual meaning^[12]. Because of the inherent passive style of lecture-based instruction, students are missing out on the opportunity to be active participants in their own learning which could affect learning outcomes^[12, 13]. More active instructional methods, such as case-based instruction, have greater appeal to those students who may be unengaged with a lecture format that concentrates on facts and content rather than the development of higher-order, and critical thinking skills^[11, 12] which are essential in the application of innovation theory. By integrating case studies into the curriculum, engineering and technology students can contextualize the content of innovation and entrepreneurship theory and view these subjects through a more pragmatic paradigm.

Best practices in case-based instruction for engineering and technology education

Although the research listed in this review suggests case-based instruction contributes to greater conceptual understanding and critical thinking skills that are needed in the engineering

profession, often engineering educators are hesitant to adopt the use of cases within their own instructional plans. Research supports a wide variety of uses for case-based instruction for all faculty members – regardless of their comfort level with this method^[14]. A survey of faculty members who use case studies in STEM education revealed varied applications for cases. One professor uses directed and highly-structured cases to reinforce content knowledge and conceptual understanding, while another professor uses open-ended, problem-based cases to encourage team building. A third educator detailed in this study uses project-based cases in his photonics course to provide authentic access to engineering culture through projects and student-driven learning^[14].

The use of case studies in engineering education will vary from instructor to instructor and from case to case. “There is no correct approach to case discussion. Each instructor must develop their own style using those techniques that best suit them and seem to achieve their objectives”^[15]. Case study analysis could incorporate the following steps: (1) review of the content of the case, (2) problem statement, (3) collection of pertinent information, (4) development of alternatives, (5) evaluation of those alternatives, (6) selection of course of action, and (7) evaluation of solutions or review of actual outcomes^[12, 15]. In a study focused on engineering decision-making, students examined the nature of an authentic industry problem. They detailed background of people and organization, the nature of the work, and challenges faced in making decisions given those constructs. Researchers then presented a specific challenge to the students for solution and discussion. In the problem solving process and case analysis, students were able to apply conceptual theory, and apply creative tools and techniques to evaluate alternatives in their decision making^[16].

For educators just embarking upon case-based instruction, an intuitive process to follow is the whole class discussion case-teaching method^[11]. This format allows the instructor to introduce key concepts at appropriate points within a discussion engaging the entire class as a single group. The instructor guides the discussion so that students “discover” the key concepts within case for themselves. This takes instructor skill and intuition to read signals from the class. To reduce the dependence of instructor intuitiveness, many published case studies include teaching notes to guide the instructor while using these discussion cases. Alternatively, the small group teaching method allows students to review the case study in advance. As part of class instruction, students work collaboratively within a small group to define the problem, conduct research, and hypothesize solutions. These groups present findings to the entire class. The instructor then summarizes and synthesizes individual group findings to support key concepts.

Research context and framework

The framework for this study is directed by the results of a larger, quantitative study examining the impact of case-based instruction on engineering technology students’ conceptual understanding of innovation curriculum as compared to lecture-based instruction. In that quasi-experimental research study, results show no significant difference in conventional knowledge acquisition or application of knowledge between the control (lecture) and experimental (case study) groups. Additionally, student attitude toward instructional method was not shown to be significantly different in this population of engineering technologists with both instructional methods scoring extremely high.

Since failure to find a significant difference in student attitude between the case study and lecture instructional methods contradicts research that shows engineering students are more engaged in case-based curriculum^[8, 16], the intent of this qualitative study is to further describe the experiences of the students who participated in the case-based instruction portion of the study. It is this study's intent to more holistically explore the phenomenon of interest^[17] and document the perspectives through the students' own description. It is our intent to interpret the content of text data through a systematic classification process of coding and identifying themes^[18]. This will be used to identify and describe key constructs and factors related to a student's experience to draw insights for current practice and future research.

Instructional method

A case from the Harvard Educator resource series^[19, 20] exploring the theory of disruptive and sustaining innovation was selected for this study. The case titled "Microsoft: Is the creative spark burning out?" introduces the theory of disruptive innovation through a historical examination of Microsoft technology and product development. This case was chosen because it provides a clear conceptual foundation of disruptive innovation theory throughout the story. The case is published with teaching notes to guide the instructor^[21]. Additionally, this case was categorized as appropriate for undergraduate students. The case-based instructional pedagogy followed the whole class discussion method of case analysis^[21]. The case study was presented to the class by the instructor of record as a reading assignment prior to the case analysis. As an invited lecturer, the researcher guided class discussion of the case study by following the case teaching notes. The case discussion included analysis of the case to provide context to disruptive innovation theory. The researcher sought input from all students through an open discussion of the case, leading students to discover the components of disruptive theory by applying them to the specific competitive opportunities and struggles Microsoft faced with their products and services.

Data Collection

As part of a larger mixed-methods study, quantitative survey data was collected to determine student attitude toward the use of case studies in the engineering and technology classroom. For the quantitative portion of the study, a Likert-type scale measured student attitude toward the case-based instructional method and was administered after case analysis and prior to a post-test. This survey was adapted from the work conducted on case-based instruction in mechanical engineering.^[8, 22] The instrument item modifications included minor changes to key words such as changing the word *engineering* to *innovation*. Internal consistency for this scale was quantified with Cronbach's Alpha $\alpha = 0.72$ which is over the commonly accepted minimum in educational research^[23]. Results from this survey indicated that overall students' had a positive attitude toward the use of case studies to learn innovation. Students agreed that case studies helped them understand (97.7%) and apply (80.2%) the theory of disruptive innovation. Students agreed the subject of innovation is relevant to real world issues (98.8%) and can see the relationship between innovation education and engineering curricula (97.7%). Additionally, students felt comfortable with the complexity of ideas presented in the case (88.3%) and view the subject of innovation as important (94.1%). Finally, student attitude reflected enthusiasm for the

subject of innovation (88.3%) and value of innovation education for the field of technology innovation (100%).

Qualitative open-ended survey

At the end of this quantitative measurement, researchers provided an opportunity for qualitative student feedback by answering the following question: “What are your thoughts about the use of case studies to teach disruptive innovation?” The majority of students provided some qualitative feedback. Using this feedback, researchers employed directed content analysis to further identify themes related student positive attitude toward the case-based instructional method and innovation theory.

Participants

Ninety students participated in the disruptive innovation case study analysis. Eighty-six surveys were completed and judged usable for this study. These students were enrolled in the College of Technology at a large Midwestern university. Student demographic information is detailed in Table 1.

Table 1: Demographic details of study population

Participants	Total = 86 no. (%)
Gender	
Male	76 (88.3)
Female	8 (9.3)
Unreported	2 (2.3)
Major	
Electrical engineering technology	41 (47.7)
Mechanical engineering technology	20 (23.3)
Industrial technology	22 (25.6)
Organizational leadership	2 (2.3)
Unreported	1 (1.2)
Grade classification	
Freshman	1 (1.2)
Sophomore	1 (1.2)
Junior	17 (19.8)
Senior	67 (77.9)
Number of students offering qualitative data	66 (76.7)

Interview

While 66 students offered qualitative data within the survey instrument, it was the goal of the researchers to further describe the experiences of students who participated in case-based instruction. At the end of the course, two sections of students in a senior capstone course (n=6) were interviewed using an unstructured, small group interview protocol allowing for a deeper description of the classroom experience. Small group interviews provide valuable insight to the interpretation of an event and provide an opportunity for students to give embellishing, interpretive data to support other forms of qualitative research^[24]. During the interview, participants discussed their opinions of case studies in general as well as their thoughts on the use of lecture-based instructional methods. Additionally, participants discussed the relevance of disruptive innovation to their future career as engineers. These students were recruited for the interview by the researcher during class time and were made aware that participation would not have any impact on their course grade and the instructor would not have access to their data and that no identifying information would be collected. The interviews lasted approximately ten minutes each and were audio-recorded.

Data Analysis

Content analysis using directed approach was guided by a structured process^[25]. An exploratory factor analysis was conducted on the quantitative section of the survey items using principal component analysis with varimax rotation. From the factor analysis, two components were identified. Based on the results from qualitative analysis and situated within the literature, the researchers identified the concept variables of student confidence and subject relevance. Next, operational definitions for each category were determined. The researchers followed the directed content analysis strategy of initial coding with these predetermined factors^[18]. Upon further analysis, the researchers separated each code into subcategories to better identify patterns and relationships between categories. This was an iterative process with themes and keywords being continually merged until the researchers were satisfied that they accurately reflected the “social reality in a subjective but scientific manner”^[26].

Results

Data from both the interview and open-ended questions is organized under two overarching categories: *confidence* in the ability to apply the subject of disruptive innovation and *relevance* of the subject of innovation to the field of engineering and technology. From these categories, four themes emerged which are illustrated in Figure 1. Results from this study are organized by these themes.

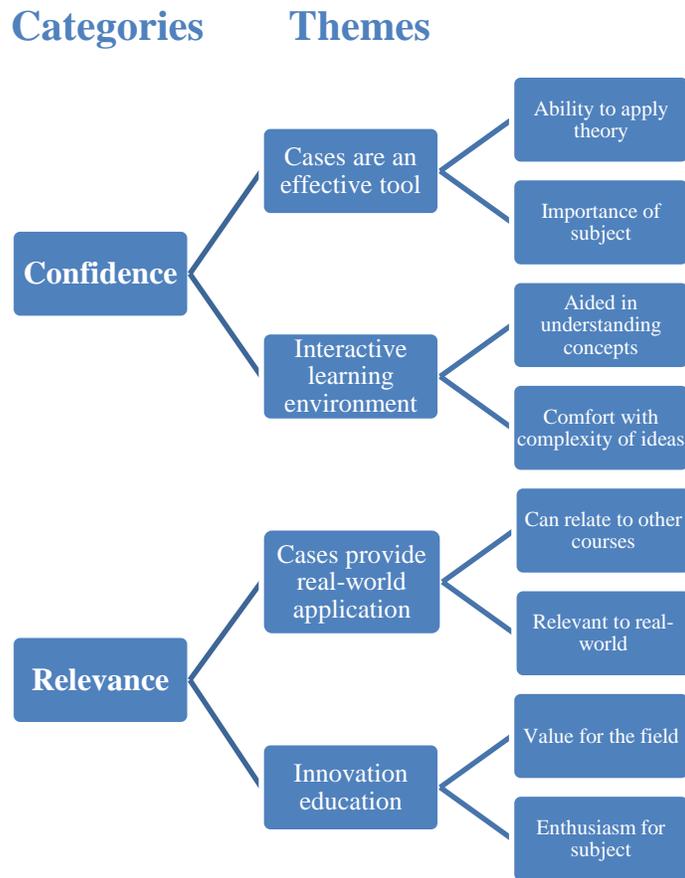


Figure 1: Categories and themes for students' attitude toward case-based instruction for innovation theory

Theme 1

Cases are an effective tool: Students reported that cases were an effective tool for learning innovation theory which includes a student's confidence in the ability to apply disruptive innovation theory after the case discussion. Case studies provide for contextual learning and situated cognition that allows them to immediately apply theory to solve problems. One student illustrated:

It forces the students to analyze the situation themselves and apply it to the information you presented them, verses just presenting the information on a slide or in a lecture, and having them try to find their own example. If you've given them one already, it's easier to relate to between cases, even.

Students reported feeling comfortable with the complexity of the ideas presented in the case study. One student discussed the use of cases:

They are effective for they demonstrate how the (disruptive innovation) affects the market. It helps a lot. For disruptive innovation is abstract, but combine with an illustration, every point makes sense.

Additionally, students believed the use of the case study aided in their understanding of the subject of innovation. Many cases begin with specific observations of data for the student to interpret, analyze, or solve. As students explore the scenario to solve the problem, they generate a need for facts, rules, principles, and theories. It is at this point, the instructor presents them with the needed material that will allow them to immediately apply context^[12]. This was supported by the following student response:

Upon reading the study, I simply saw the rise and plateau of Microsoft. Once presented the theory of disruptive innovation a lot more facts became obvious. I was able to put actual meaning and relevance to what I read.

Case-based instruction allows students' to search for creative solutions to authentic programs and experience failure, free from risk. Risk taking has been identified as an attribute of the innovative engineer. This is further illustrated by one student's response:

Learning by failure is the best way to learn. Case studies allow you to see the failures and why they happened without having the risk.

This comment supports research that finds many practicing engineers are risk-averse. Although risk-taking is viewed an attribute of innovative and creative engineers, some companies are more apt to punish failures, stifling the motivation of many practicing engineers^[2].

Theme 2

Case-based instruction offers an interactive learning environment: Students are more engaged in coursework when case studies are included in the curriculum^[27]. Students who participate in curriculum based *activities* are not only more motivated, but rank these instructional methods higher in interest, participation, and perceived knowledge transfer^[28]. One student provided the following perspective from the interview:

I don't like lectures because the students are sitting there listening and they're not really, truly engaged in it. You can't really present a case study necessarily in a lecture, its better used towards a class discussion, where everyone's engaged, and everyone's discussing and bringing up different points and views on it.

Because the learning is active, implementing case-based instruction as a pedagogical tool provides the opportunity to shift the emphasis from a professor-centered to a student-centered environment^[5]. In support of active learning pedagogies, one student offered:

I was very happy to interact and discuss the concept. I felt as if speaking about it was extremely helpful and the fact that it was interactive was even more beneficial.

One participant in the interview discussed how case-based instruction challenges engineering and technology students to develop the necessary "soft skills" of communication and team-based collaboration:

That really helps because engineers are known for their lack of interaction and so I think having interaction makes them more accustomed to the interaction they're going to have in the field in the industry because they're not going to be able to figure out everything by themselves. They are going to have to ask people from other companies, or people within you own company, about how to do a certain task or what not, and so it does prepare you in that way.

This addresses the need to build upon the traditional engineering student's course-focused concentration on subject and disciplinary knowledge by including real-world challenges within the program structure to promote innovative thinking, creativity, communication, and teamwork.

Theme 3

Case studies provide real-world application: Engineering programs have been criticized for a perceived gap between active real-world experiences and passive classroom experiences^[29]. Case-based instruction in engineering and technology allows educators to bridge this gap by engaging students in the material while adding a sense of realism to the content^[8]. On the open ended question, a student stated:

I like the use of case studies to teach disruptive innovation. I think that it gives the student something a real tangible example to look at and relate the concepts to.

Another student supported the importance of authentic problem-solving:

I think real world examples are some of the best ways to understand the way how real world problems are solved.

Theme 4

Innovation education: In addition to discussing the use of cases in the engineering and technology classroom, participants offered responses that were focused on the innovation curriculum itself and how it relates to engineering education and the field of technology. This was illustrated by the following student response:

I think that it is very important to teach this to engineering technology students because the technology industry relies on disruptive innovation. That is how the biggest strides in industry have been made.

Discussion

Results indicate engineering technology students have a positive attitude toward the use of case studies to learn innovation theory. Two overarching categories were associated with the use of case studies to teach innovation; confidence and relevance. The category of *confidence* includes themes related to understanding the concept of innovation, recognizing the importance of the curriculum, confidence in the ability to apply theory to practice, and comfort with the complex ideas inherent to innovation education. Additionally, the confidence category is associated with the factors directly related to the case-based instructional method itself such as active learning and student attitude toward the case discussion format. The category of *relevance* includes themes related to the subject of innovation and the students' perceived value to the engineering and technology profession. Two additional themes associated with category of relevance were the use of cases to link education to real-world application and the relationship between innovation and engineering courses.

The active learning environment provided by case discussions allows for discovery and inductive learning. As educators we can help our students by better bridging the gap between theory and

application by using innovation-focused case studies to illustrate the types of ill-structured problems (and opportunities) our students will face throughout their careers.

Additional research is needed to assess what active learning instructional methods are effective for the engineering and technology classroom. Equally important is the need to disseminate and discuss those findings in conversations, meetings, scholarly journals and professional conferences. Most faculty are introduced to innovative instructional strategies through casual collegial conversations followed by journal articles^[30]. Emerging educational research should be shared with peers through professional organizations, conferences, journals, and workshops.

As innovation education is more widely accepted in engineering and technology education, faculty will need sufficient time and resources to effectively develop curricula and fine-tune instructional methods. Along with new curriculum, educators should develop and research meaningful assessments and measurable impacts of innovation courses and programs. Since innovation education is an emerging field, there is limited research on how to effectively measure its impact on the field of engineering as a whole. Additionally, research is needed to support the development or modification of accreditation criteria and examine the role accreditation can play in insuring quality and consistency among entrepreneurship and innovation educational programs.

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