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Learning Through Entrepreneurially Oriented Case-Based Instruction*

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As an increasing number and proportion of engineers engage in endeavors that involve technical, socio-economic, and cultural complexity, there is likely an increased need for broader skill sets than those honed in typical engineering coursework. In particular, much of engineering education is focused on developing problem-solving skills in situations for which there is an accepted problem-solving paradigm. However, when novel problems arise and a prevailing paradigm ceases to work properly, these problem-solving skills are likely to be ineffective, resulting in inconclusive or flawed results. Future engineers must therefore learn to identify when the prevailing paradigm is flawed and successfully manage such situations in order to solve problems for which no readily available solution exists. To help engineering students develop such skills, educators should likely provide educational experiences that motivate students at both a cognitive and meta-cognitive level and allow students to recognize potentially flawed paradigms so they can tackle ambiguous and ill-structured problems. In many ways, the skills required for this type of problem-solving parallel the attributes of another class of professionals—entrepreneurs, as entrepreneurs routinely seek to break with accepted norms and pioneer new approaches to problems they observe in their environment. With this analogy in mind, this paper presents results from the implementation of an entrepreneurially oriented case study as a means to enhance engineering student attitudes and perspectives on problem-solving and learning.

Keywords: case-based reasoning; engineering education; problem-solving; ill-structured problems; engineering entrepreneurship

1. Introduction

There is general recognition that an increasing number and proportion of future engineers will face challenges that require much broader skill sets than those honed in typical engineering coursework which primarily emphasizes the technical facets of the field [1]. While engineers in the past certainly tackled complex challenges, engineers operating in the future are more apt to require interdisciplinary and potentially trans-disciplinary approaches to their work that are characteristic of complex problems that link science, technology, and social systems [2–5] and of efforts to innovate at the interface between perspectives [6-7], particularly as they strive to tackle challenges in an economic and cultural context that is arguably more global than at any time in our history. Such work environments will be inherently ill-structured and complex due to conflicting goals, unanticipated problems, multiple solution methods, non-engineering success standards and unavoidable constraints [8]. Thus, there is a need to provide future engineers with a multi-faceted educational experience that will help them master technical challenges, while also enabling them to address the less structured, and more intangible issues [9]. Such educational experiences require pedagogical approaches that motivate students at both a cognitive and meta-cognitive level, and provide students with a well-structured, organized approach to tackle ambiguous problems and unstructured environments.

In this context, this paper presents an effort to enhance engineering student attitudes toward learning and perspectives on problem-solving through the use of a case exercise founded in entrepreneurial contexts. Measures of students' attitudes and engagement are employed as an early proxy for learning and perceptions about problem-solving [10]. The case study was implemented in a senior/graduate level class about entrepreneurship and business strategy in engineering. Findings suggest that the entrepreneurially oriented case with the associated learning objectives motivated students at both a cognitive and meta-cognitive level to recognize flawed paradigms and tackle ambiguous problems and unstructured environments in a well-structured, organized manner.

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2. Training engineers for the future—a shift in paradigms

Problem-solving under defined paradigms is procedurally instilled in engineering education [11] and accounts for the majority of the educational content in most engineering curricula [12]. These problem-solving methods require students to break problems down into givens, goals, and assumptions and then to apply a well founded approach to solve the problem. This process works impeccably well in situations where there is a clear set of goals accompanied by an accepted set of assumptions. Scholars in the field of strategic management have named such an approach a deliberate strategy [13]. A deliberate strategy has precise intentions (clear set of goals), it is accepted by the majority of actors in a community (accepted assumptions), and the accepted assumptions and goals lend themselves to success. Fig. 1 shows the components of problem-solving methods under a working paradigm.

However, when the goals change and the assumptions and strategies no longer apply, old paradigms cease to work properly, leading to inconclusive or flawed results, and the potential for a paradigm shift. To this end, when a person encounters a problem for which their prevailing model is inadequate, they must re-examine their approach to make progress. Those who successfully solve the problem are the ones who *realize that the paradigm is not adequate* and are able to formulate the problem in a new manner—that is, they innovate and change the rules of the game.

In order to enable students to recognize flawed paradigms they must be prompted to notice patterns from cases in which the prevailing paradigm is flawed [14]. The need for this phase of education is reinforced by Schwartz et al. [15], who identified the need to train students to be able to learn for themselves and make their own decisions in the future. They suggested that in order to achieve these outcomes, instruction should be pursued along two dimensions of learning: efficiency and innovation. Efficiency denotes rapid retrieval and accurate application of appropriate knowledge to solve a problem. This is analogous to the problem-solving skills taught in engineering. The innovation dimension represents the ability to rearrange the environment and to think in new ways in order to handle new types of problems or information—in other words, the ability to solve a problem with an undefined paradigm. Training an individual to become competent along both dimensions yields adaptive experts: individuals capable of transferring knowledge to create new procedures for solving unique problems [16]. Development of the skills associated with this latter innovative ability is uncommon in the formal training of engineers today. However, these skills represent the hallmark of another category of successful professionals that can serve as a model for effective problem-solving in contexts of flawed or undefined paradigms—*entrepreneurs.*

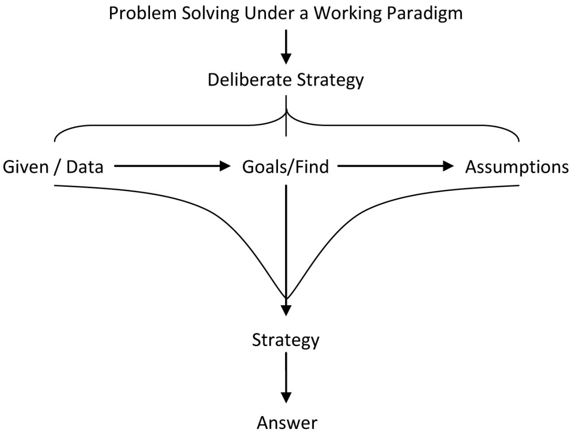

Fig. 1. Problem solving under a working paradigm.

2.1 Entrepreneurs as an analog for future engineers

The nature of entrepreneurial endeavors inherently involves uncertainty and requires entrepreneurs to adapt their knowledge, skills, and thinking to their circumstances. To do this, entrepreneurs typically challenge the status quo to pursue innovative ideas through an iterative approach to problem-solving that, in contrast to deliberate strategy, is sometimes referred to as emergent strategy [13]. In emergent strategy, the approach to a problem for which the problem-solving paradigm is flawed or undefined is allowed to develop as problem exploration unfolds. As a result, the emergent strategy process readily aligns itself to circumstances where there is no working paradigm. The components of the method are the same as those involved in deliberate strategies, but the approach is inherently different. Within this approach, a goal is formulated, underlying assumptions that must be true to achieve the goal are defined, and tests are performed to assess the validity of the assumptions. This is a process of discovery that goes through iterations, often multiple times, in order to achieve success, and thus define a working paradigm. Fig. 2 shows the components of this problem-solving method under a flawed or an undefined paradigm.

Although the problem-solving method employed by entrepreneurs seems different than that typically utilized by engineers, in principle, it is also applicable to engineering contexts as entrepreneurs and engineers share many common challenges. Entrepreneurs focus on the needs of their existing or

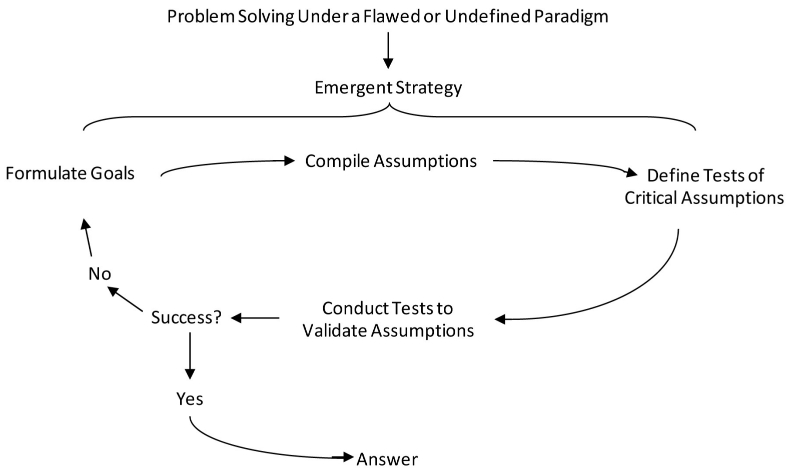

Fig. 2. Problem solving under a flawed or undefined paradigm.

anticipated customers much as engineers develop an understanding of the needs of their project and the inhabitants in the environment in which that project must be created. As the entrepreneur develops products or services for a customer base, the work of the engineer is targeted toward the development of technological solutions that address emerging needs in society. Further, to succeed, entrepreneurs must develop a means to deliver their offering to their customers in a cost-effective way that generates the profits required for their nascent business to grow and flourish. In the same manner, engineers must evaluate new technological concepts and adapt their 'development and commercialization' approach to ultimately deploy 'solutions' to facilitate long-term sustainability of the engineered system for the benefit of its users. Finally, despite the general perception that entrepreneurs are 'risk-takers' which implies a gambler-like disposition, entrepreneurs are actually active risk mitigators [17], carefully managing resources and weighing options to extend the life of their enterprise (as the consequences of insolvency, inferior product, or operational lapses are severe). In a similar manner, engineers must assess a multitude of factors in their design, planning and implementation activities, and balance a desire for conservatism with the practicality of resource availability.

The sections above have highlighted that 1) if engineers are to tackle the problems of the future successfully, they should be excellent problem solvers in situations with well defined, as well as flawed or undefined, paradigms and that 2) they may be able to learn these skills through the study of problem-solving in entrepreneurial contexts. The entrepreneurial skills, however, are not easily taught. Letting every student be a true entrepreneur is impractical, as their actions involve cost and risk that cannot be afforded to students on a large scale. Instead, this type of instruction requires a pedagogical approach that creates an environment that guides students through the shift in paradigms. One way to provide such educational opportunities is by implementing a case study designed to instill the learning outcomes described above.

2.2 Case-based instruction as an effective learning technique

Research in cognitive sciences has shown that when people acquire new knowledge, unless they learn in multiple contexts, their knowledge becomes contextualized to a point where it may cause them to fail to transfer their knowledge from one context to another [14, 18]. Further, 'research on expertise suggests the importance of providing students with learning experiences that specifically enhance their abilities to recognize meaningful patterns of information' [14, p. 36]. Similarly, in order to enable students to recognize flawed paradigms they must be prompted to notice patterns from cases in which the prevailing paradigm is flawed [14].

Case-based instruction, a problem based learning technique, addresses these issues by conditionalizing students' knowledge, helping them understand 'when, where, and why to use the knowledge they are learning', and requiring them to integrate multiple sources of information in an authentic context [14, 19]. Case-based instruction also helps students develop their own unique problem-solving skills and reason through ambiguous environments in which solutions are not easily obtained [20]. The case study method is an effective teaching tool because of the technique's ability to bridge the gap between theory and practical situations. Case-based instruction is rooted in a cognitive and socio-cultural constructivist perspective that emphasizes students taking an active role in learning through conceptual activity and social interaction with peers using problem related and collaborative practices [21–23]. This method has a long and effective history in the business, law, and medical fields to teach students the complexities and ill-structured nature of those disciplines [21, 24].

Case-based instruction has several components. First a case study is handed out to the students prior to or during class. The students then work through the case and must develop a response to the situation exemplified by the case. In order to prepare students to analyze real-life situations, case studies mimic a realistic scenario by including all of its cross currents and subtleties, including irrelevancies, dead ends, biased information, and non-linear structures [25]. Students learn to filter out distracting information, furnish missing information with inferences, and associate evidence from different parts of the case and integrate it into a solution. In a typical case study experience, students work on a problem(s) that does not necessarily have a clear solution or answer. Thus, the case study method requires students to develop analytical and decision making skills while learning the tools and theories inherent to the teaching objective.

In engineering, the case study method has been shown to enhance participants' 'ability to identify, integrate, evaluate, interrelate and understand the principles of team working and decision-making concepts' [26, p. 444]. It places engineering students in a situation where they have to think and express themselves with different representational methods, namely the written and spoken word, as opposed to merely numerical representation methods that lend themselves almost exclusively to mathematical algorithms [27]. This is not to say that the latter is not important or practical. Quite the opposite, but explaining a technical concept to an individual is meaningless unless he or she is technically literate and understands the meaning of the concept. Thus, case-based instruction trains the engineering students to work and express themselves at the intersection between representative science and other non-related domains and to develop their oral communication skills [24]. This is crucial because it gives the engineering student an augmented ability to operate within and between different domains. The advantages of case-based instruction carry over into the development of broadly useful problem-solving skills, which allow students to become flexible thinkers and to transfer their knowledge to novel situations [28].

Prince and Felder [29] have found inductive teaching methods, such as case-based instruction, to be at least equal and generally more effective than traditional teaching methods in achieving a broad range of learning outcomes in engineering. Case-based instruction 'can also provide an excellent environment in which to address . . . outcomes such as acquiring an understanding of professional and ethical responsibility, knowledge of contemporary issues or the ability to understand engineering solutions in a global and societal context' [29, p. 134].

Building on the principles outlined above, the research team developed, implemented, and tested student's perceptions of the use of an entrepreneurially oriented case study in a senior/graduate level class that offers students the opportunity to learn about entrepreneurship and business strategy in engineering. Previous research has suggested that there is a strong relationship between students' interest and their learning, and that interest plays a role in their ability to recall and remember (See [10] for a detailed review on interest and learning). Hence, the authors focused on students' attitudes and engagement towards the case study approach as an early proxy for learning, while also exploring student attitudes and perceptions about problem-solving that were influenced by the case. Below are the findings from this experience.

3. Methodology

Twenty-eight (28) engineering students enrolled in a senior/graduate level Civil Engineering course that offers students the opportunity to learn about entrepreneurship and business strategy participated in this study. The majority of the participants were male (N=21) with seven females (N=7). Nine of the participants were undergraduate seniors, fourteen were enrolled in a master's program, and five were doctoral students. There were twelve Caucasian, seven Asian, five African American, two Hispanic, and one Middle Eastern (one student did not report ethnicity).

3.1 Pedagogical design

The course involved both traditional lecture-based and case-based instruction. In this instance the case-based instruction involved use of an entrepreneurially oriented case study to provide students with a problem for which they had no working paradigm. In the opening paragraphs of the case study a problem was given. Details and complications of the situation followed, and finally, data pertinent to previously known, but inapplicable models was introduced. The goal of this particular design was to provide the student with a novel problem and allow them to use a flawed paradigm when trying to solve it. The impetus behind this was to introduce the engineering student to problem-solving under flawed paradigms by allowing them to make a mistake in a controlled environment.

Specifically, the case study placed the engineering students in the shoes of John Pope, a young project engineer at a hard drive manufacturer. In the case, John receives a note from his boss asking him to present ideas on how to segment the audio equipment market in order to innovate within it and drive new avenues of growth for the company (a challenge faced routinely by entrepreneurs and intrapreneurs alike). John performs research on the market by personally visiting electronics stores and examining several industry research reports (included with the case study). After performing initial analysis, John finds that the market segmentation schemes provided in the reports (e.g., market share by consumer age, sales volume by device type) are not only incongruent, but do not match his own observations of how customers in the market really behave. He observed far more categories of devices than were presented in the reports, and witnessed consumers of all ages purchasing varying types of devices. As John internalizes the data and his observations, he concludes that the segmentation schemes presented by those currently studying the industry fail to capture its complexity. John then has to come up with an appropriate way to segment the audio equipment industry that encapsulates his findings to identify opportunities for innovation.

The cognitive and meta-cognitive learning objectives of the case study were:

- Cognitive: To introduce the student to the concept of 'jobs-to-be-done' [30], and allow them to develop an understanding of the jobs-based view of markets. The 'jobs-to-be-done' framework focuses on the fundamental problem a customer is trying to solve in a given circumstance. This is a perspective commonly adopted naturally by entrepreneurs, yet one that is quite different from the product or demographic segmentation schemes often employed by established organizations to characterize markets for existing offerings by anchoring on attributes of consumer purchase rather than cause and effect relationships [17]. The jobs-to-be-done approach leads to a segmentation scheme based on the specific objectives of consumers and the obstacles that limit consumers' ability to achieve their objectives in any given situation, thereby highlighting situations that may be unsatisfactorily served and thus ripe for innovation.
- Meta-cognitive: To help students recognize and beware of operating with flawed paradigms when trying to solve a novel problem.

3.2 Case administration

The students in the class were divided into teams of three to four individuals and were handed the case study for reading and then further discussion among their team members. They were then asked to develop a solution to the case study and present their solution to the class. The solution was to consist of a novel way to view the radio equipment market that would highlight potential growth opportunities as well as a means to learn about the major assumptions underlying the proposed solution (i.e., how to pursue an emergent strategy to assess the validity of their hypothesis).

Of the 10 groups formed in the class only one presented a segmentation scheme for audio equipment that varied from the given views of the market. Students in this group indicated that growth in audio equipment, and thus opportunities for innovation, might be related to *where* one might want to use audio equipment (e.g., outdoors vs. indoors)—a framework that lacks the subtlety of the functional, social, and emotional insight of a full-fledged jobs segmentation, but is none-the-less a step away from the constructs provided with the case. All of the other groups regurgitated various cuts of the given data or crossed device type and consumer age to create sub-segments—all approaches that provided little help in uncovering innovation opportunities, as they simply recast what has already been done in the market.

After reviewing each team's solution, the flaws of the status quo approaches to market segmentation were discussed. The concept of 'jobs' was then raised and the instructor facilitated a discussion of the way in which thinking about 'circumstances' and the problem a consumer is trying to solve could completely change one's view of the audio equipment market, for example highlighting opportunities to tailor audio equipment for circumstances when one is alone, with friends, or in crowds, when *some* music is better than none, or when a consumer might want control of their music selection versus when they might want to be surprised or entertained by variety. Each of these circumstances is associated with different performance requirements for circumstance-specific objectives and provides seeds for innovation. The class also discussed ways that in-market experiments could be carried out to study these specific circumstances and thereby assess their hypotheses. By critically and objectively evaluating existing paradigms, and applying a new problem-solving approach, the students began to see the solutions missed in their earlier 'flawed' constructs.

3.3 Instruments

All participants completed a 23-item Likert scale survey to measure their engagement and motivation in response to the case study (the survey was adapted from [31]). They also completed a second survey that asked them to directly compare their learning experience from case-based instruction to traditional lecture using nine items. Table 1 presents the questions and results of the 23-item Likert survey. Table 2 includes the questions and results of the case vs. lecture survey. The internal consistency reliability was assessed across all items on the first survey using Cronbach's alpha (α = 0.893). Participants anonymously completed these surveys at the end of the course. Finally, students were selected to participate in a semi-structured interview in order to gain deeper insight into how the case study achieved specific learning outcomes. These half-hour interviews took place four months after the experiment in order to let the students reflect on the experience and have the opportunity to apply their new knowledge to new situations.

4. Results and discussion

This research suggests that the entrepreneurially oriented case with the associated learning objectives helped motivate students at both a cognitive and meta-cognitive level to recognize flawed paradigms and tackle ambiguous problems and unstructured environments in a well-structured, organized manner. More specifically, students reported that the case study approach supported their analytical

Table 1. Student Responses to the Use

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
The case study added a lot of realism to the class	0	3	2	15	8
The case study helped me analyze the basic elements of the course concepts	0	3	3	17	5
The case study took more time than it was worth	0	14	7	7	0
I felt that the use of case study in the course was inefficient	2	14	8	3	1
The use of case study allowed for more discussion of course ideas in the class	0	2	4	17	5
I was frustrated by the ambiguity that followed when using the case study	2	10	7	9	0
The case study allowed me to retain more from class	0	4	9	12	3
The case study allowed for a deeper understanding of course concepts	0	4	8	12	4
I was able to apply the course concepts and theories to new situations as a result of using the case study	0	2	3	19	3
I found the use of case study format challenging in the class	0	2	8	13	5
I thought the use of case study in the class was thought provoking	0	3	5	17	3
I was more engaged in class when using the case study	0	1	7	16	4
I felt that we covered more content by using the case study in the class	0	7	15	4	2
I felt that what we were learning in using the case study was applicable to my field of study	2	6	11	6	3
I took a more active part in the learning process when we used the case study in class	0	2	9	16	1
The case study brought together material I had learned in several other courses	1	10	12	3	1
I needed more guidance from the instructor about the use of case study in the class	0	7	9	10	2
I felt immersed in the activity that involved the use of case study	0	7	4	13	2
The case study was more entertaining than educational	0	12	11	4	0
I felt that the use of case study was relevant in learning about the course concepts	0	3	2	19	4
The case study allowed me to view an issue from multiple perspectives	0	4	3	14	7
The case study was helpful in helping me synthesize ideas and information presented in the course	0	1	2	20	5
Most of the students I know liked the case study	0	4	14	7	3

Note: The numbers in the table represent number of students that responded under each scale.

Table 2: Student Comparison of Case- and Lecture-based Learning

In learning about entrepreneurship concepts, I felt I:	Lecture		Neutral		Case study
	*	*	*	*	*
Was frustrated	0	3	13	7	5
Was active	1	2	9	8.5	7.5
Was motivated	3	2	12	5.5	5.5
Was challenged	3	2	6	8.5	8.5
Was engaged	4	3	5	12	4
Was confused	3	2	10	5	8
Developed a better understanding of the concepts	5	7	4	5	7
Needed more guidance from the instructor	3	3	6	8	8
Learned more	8	5	6	6	3

Note: Non-integer values reflect ratings bridging two possible responses.

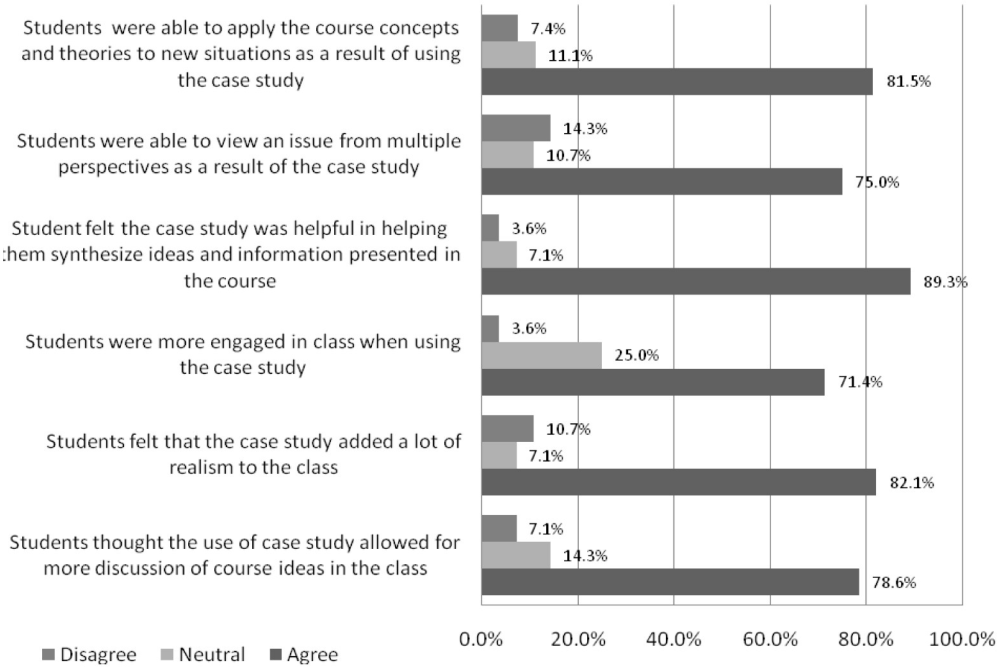

Fig. 3. Highlights of Likert survey responses to use of the case study.

skill set, and helped bridge theory and practice. Finally, as a teaching tool, the case study method was well received by engineering students.

As highlighted in the selected Likert survey results summarized in Fig. 3, the majority of the students reported that the use of the case study allowed them to apply the course concepts and theories to new situations (81.5%). Further, due to the non-linear nature of the case, along with the mix of important and unimportant material it included, students had to dig for information and make inferences between elements of the case material. This allowed the students to develop analytical skills and their abilities to interpret an issue from multiple perspectives (75.0%). These results reinforce the notion that the case study method is an effective teaching tool because of the technique's ability to bridge the gap between theory and practical situations. Students also reported that use of the case study allowed them to synthesize ideas and information presented in the course (89.3%). For instance, in one interview a student stated: 'it did help put things in perspective. It was like: ahhh, ok, so that's what [the professor] means.'

The Likert survey also revealed that, as a teaching method, the engineering students welcomed the case study. Students reported that the use of the case study increased student engagement in class (71.4%), added more realism to the class (82.1%), and also allowed for more discussion of course ideas (78.6%). For example, one student stated: 'it really helped put real world application to an otherwise lecture style course.' These views were further supported by the second survey directly comparing the case study with traditional lecture as summarized in Fig. 4. Despite involving higher levels of frustration and confusion, and requiring greater instructor guidance, the case study was generally shown to be more active, challenging and engaging than lecture and facilitated comparable understanding. Students did report slightly greater learning from lecture relative to the case study, and this may support the notion that case-based instruction is an effective supplement to traditional teaching approaches, but not a substitute.

As mentioned above, the case study was designed to provide students with a problem for which they had no working model. Students attempted to solve the problem using data and strategies applicable to prior known, yet inapplicable paradigms. The solutions students developed were flawed. After presenting their solution, the students and the professor engaged in a discussion where, along with the contextual information regarding the lesson, the notion of considering whether the current paradigm works or not was introduced. For instance, one student stated: 'our solution for the case study was wrong . . . . [The exercise] was misleading, but in an appropriate way. The whole point of the exercise was to get you to think a little outside of what's thrown at you or what is given directly to you, so it led you down this little pathway with, you know, in-the-box data, if you will, and it was very hard to deviate from that data when that was the exact

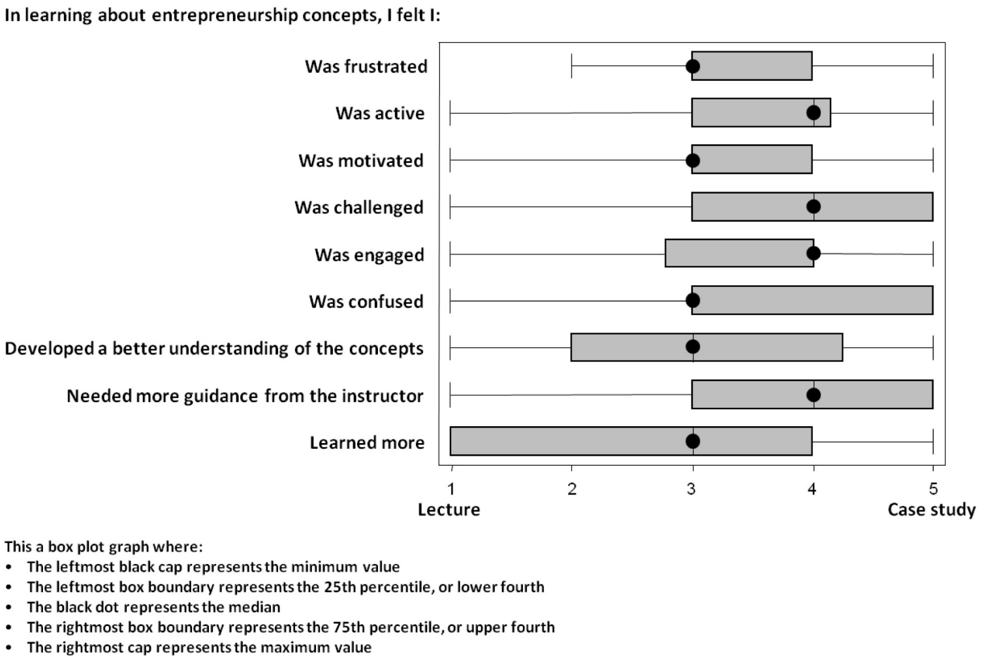

Fig. 4. Summary of student comparison of case- and lecture-based learning.

purpose of this exercise: to get you to ignore what's in front of your face and to think for yourself.'

In interviews after the completion of the course it was clear that students had internalized the case's key lesson and became aware of the importance of recognizing when previously known paradigms become irrelevant. One student stated: '[the exercise] did open our eyes to what we weren't doing . . . it opened my eyes to say: ok, why am I using what I'm using? Is it just because it's there? Or, is it really what I should be using? . . . It was an awareness thing.' Another student shared similar views and stated: '[what I got from the exercise was to] come up with your own model, rather than totally depending on someone else's model.' This was an exercise in augmenting students' innovation dimension in learning, and furthermore, training them to become capable of handling novel and unstructured problems.

5. Conclusions and future work

The engineering problems of the future will likely require inherently different approaches from the norm today. In order to prepare engineers for the future, engineering educators should provide educational experiences that motivate students at a cognitive and meta-cognitive level in order to train them to construct effective solutions at the intersection of varied fields. Moreover, educators should pursue learning objectives along the dimensions of both efficiency and innovation in order to create engineers that can solve problems in recurrent and novel situations. Developing adaptive expertise within the engineering student could yield professionals capable of rearranging the environment and thinking in new ways to handle novel or unstructured problems in a well-organized and structured manner—much the same way entrepreneurs perform every day.

Case-based instruction using entrepreneurship concepts engages students at cognitive and meta-cognitive learning levels. Furthermore, early evidence seems to indicate that the case study may be an adequate teaching vehicle for such learning outcomes because of the technique's ability to bridge theory and practice, require students to develop analytical and decision making skills, and engage and motivate students to learn by situating learning in authentic and meaningful contexts. Additionally, results from this study, although limited in scale and scope, suggest that students thought the case study was relevant to developing entrepreneurial thinking as it allowed them to apply the course concepts and theories to new situations. It is important to note that only student perceptions of the case study approach were measured in this study and not their ability to transfer their learning to new situations. Hence, the current findings are limited to students' attitudes towards case studies. Future research needs to investigate the impact of the case study approach by measuring student learning outcomes. In addition, future work should examine whether cases can be applied across all engineering disciplines and impact student learning at all levels of engineering. Recall that the current research implemented case studies in a graduate level course on entrepreneurship that included both graduate students and seniors; this is a group that typically has adequate disciplinary knowledge. Thus, there would also likely be merit in understanding how much background knowledge students need to successfully learn from cases.

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