International Journal of Engineering Education Vol. 35, No. 1(A), pp. 109–118, 2019
Printed in Great Britain

0949-149X/91 $3.00+0.00

Reinvigorating Classroom Engagement and Performance in an Advanced Energy Systems Course*

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Today, the technology landscape is at a highly competitive playing field forcing companies to seek engineers who can provide the upper hand over others through innovative thinking. This study presents a Fuel Cell Science and Technology course focused on encouraging innovative thinking by adopting a T-shaped philosophy through the principles of incorporating greater perspectives, active learning environments, and practical lectures into the classroom. The course was offered for two years in which 67 undergraduate and graduate students were enrolled. During that time, student performance and engagement was monitored using standard course evaluations, anonymous surveys, and classroom observations. Course evaluations and survey results found that all participating students were able to demonstrate a deep understanding of the course content. A discrepancy between undergraduate and graduate students' survey responses were also observed, possibly suggesting a difference in student engagement based on student background.

Keywords: T-shape philosophy; innovative course curriculum; advanced energy course

1. Introduction

The world has moved into a new era of globalization, connecting people, companies, and nations to collaborate and develop new innovative technologies [1]. Consequently, providing the ability to share ideas instantly has created an aggressive economic climate where corporations are continually seeking a competitive advantage [2]. To do so, corporations rely heavily on innovative thinkers who create groundbreaking designs and solutions. In the United States, there is a growing need to develop creative and innovative engineers that have a competitive advantage in a global economy [3, 4]. This lack of engineers raises the question of how to educate the future generation of innovative thinkers to compete in this new era of globalization [5].

Several researchers have speculated that one solution might be to add a creative aspect of thinking to their engineering curricula, allowing students to gain a well-rounded perspective of subjects which would teach them how to make insightful decisions [6, 7]. To produce innovative engineers, several institutions have adjusted their engineering curricula by incorporating a T-shaped philosophy into their classrooms. When a T-shaped philosophy is adapted into the classroom, it combines the depth of the engineering discipline with the breadth of the discipline's broader perspective (Fig. 1). As a result, students can become experts in their engineering disciplines while also gaining transferable skills which are adaptable to other fields [8, 9].

A T-shaped philosophy curriculum can be implemented through a combination of different learning strategies (e.g., lecture, active, or problem-based learning) [10–13]. The combination of different learning strategies allows students to find the learning method that is most appropriate for them, which has been shown to influence students' engagement with the course content [14–17]. Specifically, students who can engage in class more have demonstrated better performance and a stronger belief in their understanding of the course content (i.e., self-efficacy) resulting in the personal growth of innovative thinking [18–22].

Olin and Dartmouth College are two examples of institutions that have already adopted a T-shaped

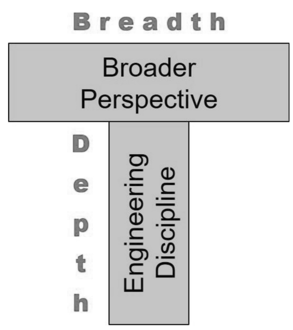


Fig. 1. The concept of a T-shaped philosophy.

* Accepted 9 September 2018.

philosophy into their curricula [23–25]. Olin College offers three engineering programs which are based upon engineering fundamentals, liberal arts, and entrepreneurship. Olin's program encourages students to strengthen their artistic interest while learning in an active interdisciplinary environment. Dartmouth College requires students to complete core liberal arts courses whose topics are integrated throughout future engineering courses. Although the program is one year longer, Dartmouth's students are awarded a Bachelor of Engineering along with a broader understanding and appreciation of liberal arts.

Although promising, several hurdles stand in the way of implementing innovative curricula at other institutions. Some researchers have speculated that if external disciplines other than engineering are valued too much, then it could deemphasize the focus on learning engineering principles [26]. Another issue is the limited time instructors are given to cover a wide variety of topics while simultaneously trying to ensure a high student success rate [27, 28]. The primary effort of achieving course objectives in a short amount of time forces instructors to focus solely on covering the course material, ultimately overshadowing the idea of incorporating broader impacts of engineering principles into the classroom [29–31]. Lastly, many institutions might lack the resources to overhaul their entire curriculum resulting in the decision to maintain traditional educational practices.

The significant hurdles raise an interesting question of how to effectively integrate a T-shaped philosophy into the classroom to encourage innovative thinking in students? One solution could be to implement a single elective course based around a specific engineering discipline which balances fundamental concepts while emphasizing practical applications and broader technological impacts through engaging teaching strategies. In doing so, the previously mentioned hurdles become simpler to overcome. More specifically, adopting innovative teaching to an elective course eliminates the risk of jeopardizing engineering students' entire education and provides more freedom to adjust the curriculum, of a single course in a well-established engineering program.

This study hypothesizes that a T-shaped philosophy can be integrated into a single elective course (Fuel Cell Science and Technology) by combining fundamental concepts of fuel cell technologies and its greater technological impacts and implications. The success of this integration was based on the students' overall performance and self-efficacy monitored through standard course evaluations and an anonymous survey distributed throughout the semester, respectively. Additional observations made by the instructor concerning students' in-class engagement with course material was also recorded by the instructor over the duration of this study.

2. Course outline

The goal of the Fuel Cell Science and Technology course was to build a curriculum based on the T-shaped philosophy to assist students in learning about fuel cell systems and technologies while gaining a broader perspective of fuel cell's technological influences and impacts. This goal was achieved through the establishment of three principles that embraced the T-shaped philosophy:

1. Engineering education is not only about quantitative analysis and technical skills, but also about synthesis, innovation, and gaining a *greater perspective* on the impacts of engineering technologies and innovations [32].
2. Engineering education should not amount to the passive delivery of material. It should offer an *active learning environment* where students can build upon the knowledge gained from classroom lectures [33, 34].
3. The classroom should include *practical lectures* which encourage useful problem-solving tools that incorporate current applications. In doing so, engineering students can apply classroom skills directly to real-world applications [13].

As demonstrated in Fig. 2, the principles of greater perspectives and practical lectures represented the breadth and depth of the T-shaped philosophy, respectively, while the principle of an active learning environment was the interconnect between the other principles. These principles were implemented in the course using various teaching strategies such as including active lecture and hands-on laboratory sections, problem-based homework assignments, in-class seminars, writing assignments, and a final case study project (Fig. 3).

The course was offered to upper-class undergraduate and first/second-year graduate students separately. Graduate students were held to a

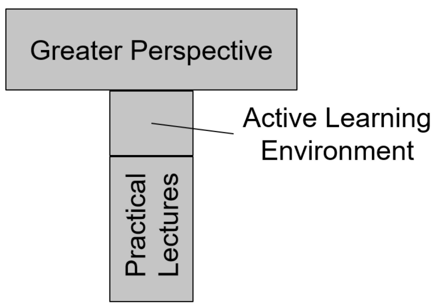


Fig. 2. Course principles adapted from a T-shaped philosophy.

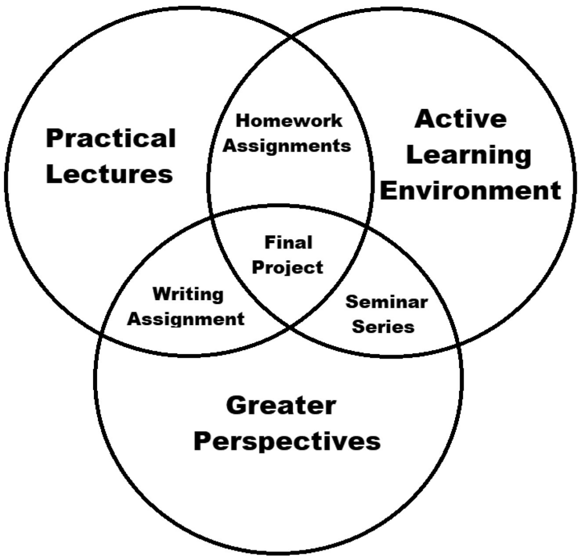


Fig. 3. Venn Diagram showing how course components were used to incorporate the overlap of the course's founding principles.

higher standard with the expectation of completing higher order calculations and derivations on their own in the course assignments. The course was divided into multiple sections to maintain student engagement throughout the semester (Table 1). The first seven weeks of the course included a standard bi-weekly lecture. The lecture included open discussions and practical examples which created an engaging environment for students to build their knowledge of fundamental fuel cell concepts.

During the lecture portion, textbook-based homework problems were assigned to allow students to engage with the lecture material on their own. Students were unaware that several of the topics presented in homework assignments would reappear in the laboratory section of the course, thus providing a pathway to reinforce textbook-based knowledge through hands-on activities. At the conclusion of the lecture portion of the course, students were given a midterm exam. The exam incorporated problems similar to homework assignments and in-class examples. The homework assignments and exam were graded using the same three criteria: (1) the student was able to solve the problem using a logical approach demonstrated in lecture or from a reputable source, (2) the student's work is organized and easy to understand, and (3) the student obtained the correct answer.

After the lecture section of the course, students participated in an open discussion seminar series which introduced broader concepts and applications of fuel cell technology. The primary goal of the seminar series was to introduce other course content while simultaneously discussing technological impacts. The series included three seminars which discussed the following topics:

1. The current state of fuel cell technology.
2. How are fuel cells made: An introduction to fuel cell manufacturing.
3. Designing a portable fuel cell system.

The first seminar was held by an experienced fuel cell engineer whose background primarily consisted of product development. The seminar included details concerning the recent developments of fuel cell technology and how economic, political, and environmental roles influence the technologies implementation (e.g., California's plan for a hydrogen economy). The second seminar presented students with different fuel cell fabrication techniques such as tape casting, dry pressing, extrusion, and dip-coating. The second seminar also acted as an introduction to the laboratory section of the course since most of the presented techniques would be used then. The final seminar was a step-by-step demonstration on how to design a fuel cell system (i.e., balance of plant). The final seminar also served as a starter to the students' final project in which they would be working in teams of three or four to design a portable fuel cell system.

Teams were chosen at the end of the seminar series. Each team would spend the second half of the semester working together in the laboratory as well as on the final project. The laboratory experiments consisted of five sessions dealing with fabrication, characterization, and testing of fuel cells. The laboratory section of the course was made possible

Table 1. Fuel Cell Science and Technology class schedule

Schedule	Week 1	Weeks 2–6	Week 7	Week 8	Weeks 9-13	Week 14
In-Class	Lecture		Midterm Exam	Seminar Series (3 Seminars)	Laboratory (5 Lab Sessions)	Team Presentations
Survey	First class survey		Midterm class survey			Last class survey
Assignments	Textbook Assignments			Final Project		
				Article Discussion/Written Assignment		

through the resources available in the Combustion and Energy Research (COMER) laboratory, directed by Dr. Jeongmin Ahn. In each experiment, groups worked together to fabricate a specific component of a ceramic fuel cell. The fabrication techniques included tape casting, dry pressing, extrusion, dip-coating, and wet powder spraying. After completing the fabrication experiments, groups would test their fabricated fuel cells for their final laboratory session.

While students were actively participating in the laboratory section, they were also working on a writing assignment. The assignment primarily focused on improving students' understanding of how fuel cells' impact broader areas outside of science and technology (i.e., political, economic, environmental/social and manufacturing) and how that impact related to the lecture and laboratory section of the course. Each week, students were assigned to find an article which highlighted fuel cell technology's relation to one of the four broader areas. After finding an article, students were required to meet with their teams to have an open discussion about what they had read and how it related to one of the broader areas. Each student then wrote a one-page summary of their selected article detailing their thoughts about how fuel cell fundamentals and technology related to that week's broader topic.

The writing assignment was graded based on content, style, and mechanics. Content specifically focused on whether the written work displayed a clear summary of the article and its link between fuel cells and broader concepts. Style determined if the written work was smooth, coherent and consistent with a central idea. Mechanics determined if the written work consisted of no errors in sentence structure, misuse of words, spelling, and grammar.

For their final assessment, groups were asked to use the knowledge and opinions they had gained over the semester to design a portable fuel cell system. Each team was instructed to act as an engineering firm which would present their design to a "board of investors," consisting of instructors and invited faculty. The design was partially constrained by requiring each team to meet specific fuel cell operating criteria (e.g., power, voltage) given the standard performance of a single fuel cell.

Teams were instructed to use system design (i.e., balance of plant) methods previously learned in the final seminar of the seminar series. The balance of plant design consisted of teams choosing different items (e.g., air blower, fan, compressor, heat exchange, DC-DC converter) from a pre-selected catalog that would be combined and designed to operate under certain conditions and meet the project's constraints (e.g., the total power generated). The cost of each item and operating conditions achieved were assigned a numeric value which contributed to the overall score of the design. The design score could be maximized when the design satisfied the specific constraints of the project. The design score's purpose was to add a financial perspective to the project which encouraged students to think about cost v. performance in their designs. The project also required teams to provide a detailed method for fabricating fuel cells using the fabrication techniques learned in the laboratory sessions.

The final project was evaluated through a 40-minute team design pitch and a final report due the following week. The presentation and report content were evaluated on the criteria that a team could explain: (1) how a fuel cell works, (2) the decisions behind their design (i.e., why they chose specific components and operating parameters), and (3) how the team planned on manufacturing the fuel cells incorporated into their design. Additionally, team presentations and reports were evaluated on their organization and mechanics. Each team presentation concluded with questions from students and the "board of investors" which provided feedback on the team's design. Teams were instructed to include the feedback from the question portion of their presentations in their final project report.

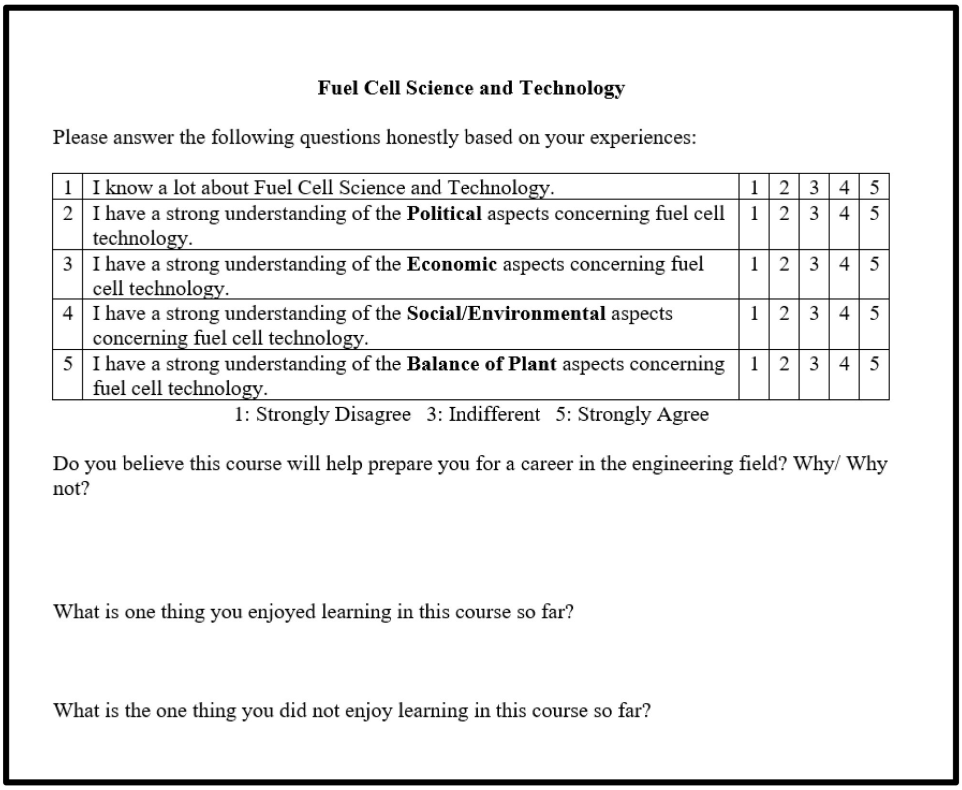
3. Evaluation and data collection

Students' final grades were determined using the grade breakdown in Table 2. Although the breakdown is comparable to standard courses (i.e., homework, exam, reports, and presentations), the grading rubric had an underlying balance between the course's fundamentals concepts and broader applications. For instance, the midterm exam is the culmination of the standard lecture content, while the write-up/discussion assignment reflects student personal exploration of broader areas. The final project combined all content taught throughout the course, it was weighted more.

In addition to monitoring student performance, anonymous surveys were administered three times throughout the semester to gain some simple feedback on students' engagement of the course material. An example of the survey is shown in Fig. 4. The survey structure consisted of five Likert-style response questions concerning individual subjects taught throughout the semester. Students' responses were quantified on a 1 to 5 scale ranging from 'strongly disagree' to 'indifferent' to 'strongly agree.' The survey's objective was to obtain insight into the overall engagement of the students throughout the semester by gauging student's belief in understanding the course content. The

Table 2. Grading Breakdown for Fuel Cell Science and Technology

Course Component	Description	Weight
Textbook Assignment	Two bi-weekly assignments	15%
Written Assignment	Four weekly assignments	15%
Midterm Exam	Four questions based on homework/lecture problems	30%
Final Project Presentation	30-minute group presentation on team's fuel cell system design	20%
Final Project Report	A written report provided by each team detailing their fuel cell system	20%
Total		100%



Fuel Cell Science and Technology

Please answer the following questions honestly based on your experiences:

1	I know a lot about Fuel Cell Science and Technology.	1	2	3	4	5
2	I have a strong understanding of the **Political** aspects concerning fuel cell technology.	1	2	3	4	5
3	I have a strong understanding of the **Economic** aspects concerning fuel cell technology.	1	2	3	4	5
4	I have a strong understanding of the **Social/Environmental** aspects concerning fuel cell technology.	1	2	3	4	5
5	I have a strong understanding of the **Balance of Plant** aspects concerning fuel cell technology.	1	2	3	4	5

1: Strongly Disagree 3: Indifferent 5: Strongly Agree

Do you believe this course will help prepare you for a career in the engineering field? Why/ Why not?

What is one thing you enjoyed learning in this course so far?

What is the one thing you did not enjoy learning in this course so far?

Fig. 4. Example of an anonymous student survey administered throughout the course semester.

survey also included open-ended questions which asked whether students thought the course was useful to their future careers in addition to what they liked and disliked about the course. The survey distribution schedule, provided in Table 1, shows the surveys were administered in class on the first day of class (Week 1), the middle week of the semester or mid-semester (Week 7), and the final day of class (Week 14).

During each semester, the instructor would also make observations regarding student engagement both in-class and during designated office hours. Any instance of a student displaying a comment or question that provoked further discussion on course content was recorded in the instructor's notes. The instructor's notes did not include any indicator of student identity and only highlighted the contribution of the student's comment/question. For example, if a student asked a question to clarify a course topic, the question was documented in the instructor's notes.

4. Results and discussion

Due to the limited laboratory space, the total class enrollment for a semester was capped at 22 students. The course was offered exclusively to undergraduate students for both fall semesters, while the spring semesters were reserved exclusively for graduate students. Most students in both the undergraduate and graduate classes were mechanical and aerospace engineering majors. Most of the undergraduate students were fourth-year seniors except for a small group of third-year students. The first-day survey included additional questions to establish class demographics/backgrounds, and the results are shown in Table 3. Table 3 shows that many of the undergraduate students had experience working

Table 3. Class demographics for each semester

Semester	Year	Class	International Students	Male	Female	Work Experience	Number of Students (N)
Fall	2014	Undergraduate	4	9	2	5	11
Spring	2015	Graduate	7	15	5	15	20
Fall	2015	Undergraduate	3	13	7	9	16
Spring	2016	Graduate	18	18	4	3	20
Total		–	32	55	18	32	67

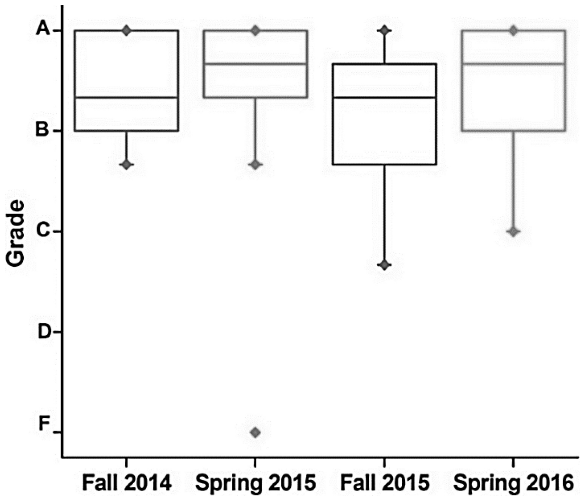


Fig. 5. The grade distribution for each semester the course was offered. Note: the horizontal line in each box represents the median mark of the semester.

in a research or industrial fields. Table 3 also shows some of the class was comprised of international students from Asian or South American countries.

The graduate student classes consisted of a larger population of international students whose nationalities stem from India, China, Korea, France, or Brazil. Typically, many of the international students were continuing graduate students, having just completed a Bachelor of Science in engineering and continuing their academic careers at Syracuse. Most domestic graduate students were also found to be continuing graduate students, apart from one student who was returning to school after five years of employment in the manufacturing field. Most of the graduate students enrolled in the course were pursuing a Master of Science in either mechanical and aerospace engineering, energy systems engineering, environmental engineering, or chemical engineering. Additionally, the graduate level course consisted of a small group of Ph.D. students with research experience, but a limited background in the fuel cell field.

Course grades were used to gauge overall student performance during the semester as well as draw comparisons between semesters and student status (graduate vs. undergraduate). The box plot in Fig. 5 offers an idea of the range of how students performed in the class. Generally, most students scored high marks with the median of each semester ranging between an A and a B+ class grade. The grades showed that 50% of the students in the graduate classes (spring semesters) scored an A- class grade or higher while 50% of the students in the undergraduate classes (fall semesters) scored a B+ class grade or higher. The Spring of 2015 semester did have one student who received an F class grade due to an external issue the student was facing at the time. Overall, the high course grades showed that students substantially satisfied the expectations of the course, indicating that students were generally able to perform well with the multiple teaching methods incorporated into the course.

Survey responses were analyzed using a one\two-way analysis of variance (ANOVA) and a post-hoc Tukey test with time of the semester and student status (undergraduate or graduate) as two factors which might influence the mean student response. The difference between semesters was initially included in the analysis but showed no significant variation or influence on the mean student response. The remaining factors did show significant relationships to changes that had occurred during this study.

Looking at the overall mean student responses of the course (Table 4), there was a significant change in the mean student response regarding student's belief in understanding the course content. The ANOVA of the mean student response of statement 1 yielded a significant variation among the time of the semester [$F(2,183) = 57.26$, $p < 2E\text{-}16$]. The post-hoc Tukey test of statement 1 showed that the student response between the last and first day of class differed significantly with a p-value less than 2E-16. The difference in statement 1 mean student responses possibly suggests that all students (undergraduate and graduate) had believed they had gained a stronger understanding of fuel cell science and technology over the course of the semester.

Similarly, statements 2–5, which focused on the broader impacts of fuel cell technologies, show a difference in the mean student response throughout the semester, with a more considerable difference between the last and middle week compared to middle and first week. The higher difference in

Table 4. The course's overall mean student response and corresponding p-value at a different time of the semesters

Statement	Mean Student Response			P-value		
	First Day (N = 57)	Mid Semester (N = 67)	Last Day (N = 61)	First Day-Mid Semester	First Day-Last Day	Mid Semester-Last Day
1	1.88	3.18	3.62	< 2.0E-16	< 2.0E-16	0.0175
2	1.89	2.41	3.52	0.0154	< 2.0E-16	< 2.0E-16
3	2.37	2.74	3.89	0.1197	< 2.0E-16	< 2.0E-16
4	2.53	2.96	3.92	0.0548	< 2.0E-16	< 2.0E-16
5	1.70	2.46	3.79	0.0004	< 2.0E-16	< 2.0E-16

the mean student responses for all statements between the middle and last week of the semester may correspond to the additional teaching strategies such as hands-on laboratory sections, problem-based homework assignments, in-class seminars, writing assignments, and a final case study project.

Additional variances were discovered for the interaction between undergraduate and graduate students and the time of the semester using a two-way ANOVA and a post-hoc Tukey test. When looking at the last week survey results, there was a considerable difference between the undergraduate and graduate mean student responses. As shown in Table 5 in last day column of the mean student response, undergraduate students had an approximate value of 1 mean student response rating higher (more "agreeable") compared to the graduate student mean responses for every statement. The discrepancy between the undergraduate and graduate survey responses raise an interesting question concerning students' belief in understanding course content, despite demonstrating a consistently high performance regardless of students' academic level previously shown in Fig. 3.

The difference between undergraduates and graduate students' belief in their understanding of the course content was further seen in the instructor's classroom observations. Undergraduate students demonstrated more creative efforts for the final design project compared to graduate students. For example, undergraduate students' final presentations and reports included innovative ideas of how to incorporate fuel cell technologies for military or residential utilization. The innovative undergraduate ideas provided in the final presentations and reports suggest that they had obtained a firmer grasp on fuel cell technology's broader impacts. Graduate students' final presentations and reports focused more on the system design, specifically developing techniques for optimizing the operating system or manufacturing process. Though it has been suggested that a certain course structure can influence individual creativity in students, it does not explain the discrepancy between undergraduate and graduate students' responses, since they both experienced the same course structure and were found to satisfy the expectations of the course substantially [6]. So why do graduate students respond less "agreeable" to their belief in understanding course topics compared to undergraduate students?

One possible explanation for this divergence may be found in the open-ended questions included at the end of the surveys. As stated before, students were asked whether they believed this course would help them prepare for a career in an engineering field with the option for an explanation. Most undergraduates agreed that this course would help, citing a collection of reasons including "learning about alternative energy" or "gaining experience in cleaner power generation technologies." Most graduate students also agreed, but with different reasoning, claiming the course would teach "energy design calculation for industry" or provide "hands-on experience that could be used in a company." Although some responses were shared among both groups, most graduate students' responses to

Table 5. The student mean response and corresponding p-value based on student status at different times of the semester

Statement	Mean Student Response						P-Value		
	First Day		Mid Semester		Last Day		First Day	Mid Semester	Last Day
	UGRD (N = 28)	GRAD (N = 29)	UGRD (N = 28)	GRAD (N = 39)	UGRD (N = 28)	GRAD (N = 33)	UGRD-GRAD	UGRD-GRAD	UGRD-GRAD
1	1.93	1.82	3.24	3.10	3.19	4.06	0.611	0.528	0.001
2	2.07	1.71	2.53	2.26	2.87	4.20	0.120	0.317	5.4E-07
3	2.69	2.03	2.89	2.53	3.48	4.30	0.017	0.147	0.001
4	2.79	2.25	3.00	2.9	3.39	4.47	0.051	0.694	6.60E-06
5	2.07	1.32	2.79	2.03	3.29	4.30	0.001	0.005	0.005

the open-ended questions primarily focused on refining professional job skills while undergraduates focused primarily on fuel cell technology and its societal impacts.

The focus on career development alternative to the technological impacts may explain why the graduate students' mean responses to each statement were less "agreeable" compared to the results of the undergraduate students. The difference between both groups could stem from the student expectations which undergraduates have compared to graduate students. Undergraduate students typically enroll in an established program that combines both core courses, engineering courses, and electives which satisfy the requirements for them to obtain their first degree. During their program of study, undergraduates may encounter some courses within their program which are unrelated to engineering and expand upon topics that may be relatable to technological innovation. Most importantly, although undergraduates choose their program of study, they do so to earn a degree and to start a career eventually.

Alternatively, graduate student programs and motivations differ significantly. Most graduate student programs, focus more on furthering a student's engineering education through advanced science and math-based courses. Engineering graduate students who have already obtained a degree, and therefore have chosen continuing education rather than joining the workforce, are more motivated to further their technical knowledge and eventually their professional status [35].

In the context of implementing an innovative course founded on the principles of incorporating greater perspectives, active learning environments, and practical lectures, the difference between graduate and undergraduate reception to the course structure provides some insight into the course limitations. Graduate students' academic motivation of obtaining an active command of technical skills to advance their professional careers could reduce student focus on connecting technology and its impacts through active learning lectures. On the other hand, undergraduate students may be receptive to understanding technology and its impacts since they are still in the infancy of their professional careers. Because of this, a course which aims to instill innovative thinking may prove to be more useful for students in the early stages of their academic career.

Another significant challenge encountered by the instructor was communicating and teaching broader perspectives of fuel cell technologies to international students. The difference between engineering curricula overseas compared to the United States has been well documented, showing a highly focused solution-based learning in international countries [36, 37]. The instructor observed that due to a variety of educational backgrounds, it was more challenging to express alternative perspectives to international engineering students without finding common ground that provided easier access to the course material. The instructor also observed that groups with students from different nationalities exhibited more diverse impacts in their final presentation and report. For example, one group comprised of students from different nationalities was able to provide detailed examples of how fuel cell technology can be beneficial to the United States greenhouse gas reduction initiative while also aid in Japan's reconstruction of its energy infrastructure.

5. Limitations and future work

Despite this case study presenting an interesting issue concerning the different attitudes between undergraduate and graduate students towards course content, the work presented in this study is limited in its scope and depth. As previously stated, the survey was initially designed to provide feedback concerning student engagement exclusively for the Fuel Cell Science and Technology course. It was not intended to identify and compare how students from different academic levels or backgrounds engage with course content in this or another course. Additionally, the survey structure consisting of five Likert-style response questions and the brief open-ended questions does not fully explore the true attitude of individual students, making it more difficult to form conclusions concerning the relationship between diversity and engagement. Lastly, the instructor observations did not focus exclusively on the different attitudes of undergraduate and graduate students regarding course content. Therefore, further research is needed to understand how to encourage innovative thinking and student engagement while considering student background.

Another point of interest for future work is the benefit of diversity among groups which significantly supported the course underlying initiative, particularly with the idea of globalization. As stated in the previous section the instructor was challenged with teaching students from various backgrounds, especially when dealing with alternative perspectives. How international student perceived the broader concepts taught in this course or how common ground could be established in the classroom and between students could be documented. Future work must further explore this issue to understand further how the exchange of ideas corresponds to a classroom's diversity.

6. Conclusions

This study presents a Fuel Cell Science and Technology course which aimed to combine fundamental engineering principles with societal implementations and broader impacts. Through a combination of teaching techniques and methods, founded on the principles of greater perspectives, active learning environments, and practical lectures, it was found that collectively students were able to meet the course expectations considerably. At the end of the course, graduate students demonstrated a lower mean response of their belief in understanding course topics compared to undergraduate students. The difference in the student mean responses could stem from a difference between undergraduate and graduate students. Overall, this study was able to demonstrate a course model which incorporated a T-shaped philosophy for encouraging innovative thinking in students. However, further research addressing the issues of how student engagement differs based on student background, as observed in this study, should further be investigated.

Acknowledgments—This work was partially supported by the Syracuse University College of Engineering and Computer Science Faculty Excellence Award and the National Science Foundation under grant CBET-1403405.

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