Implementation of the Question Formulation Technique as a Teaching Strategy in Renewable Energy Engineering Education

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Abstract

The Question Formulation Technique (QFT), a powerful yet simple teaching strategy recently featured in an ASEE online webinar, teaches students how to formulate, work with, improve, and use their own questions. As a result, students become more confident researchers and better value the role of question formulation in the learning process [1]. While the QFT has been widely used in other educational settings, its adoption in higher education has recently been accelerated in-part because of a National Science Foundation research study. In this work we demonstrate two unique, innovative ways to integrate the QFT as a teaching strategy for renewable energy engineering students. First, we will make visible how the QFT was utilized in a junior level class in Materials for Renewable Energy Applications to develop the outline of a term research paper. Secondly, we will share how the QFT was used in a cross-listed senior/graduate course in Bioenergy to develop a research topic. The QFT's impact on student learning will be described and eminently practical details for integrating the QFT into engineering coursework will be outlined.

1. Introduction

The Question Formulation Technique (QFT) is a teaching strategy first made widely available to the field of education in the book *Make Just One Change: Teach Students to Ask Their Own Questions* [2]. Since the publication of the book, the strategy has been used across all grade levels [3]—from pre-k through higher education—and across subject areas. The strategy has been used by over 250,000 educators [4] in over 150 countries, and recent National Science Foundation funded research suggests that after a one hour experience in the QFT, doctoral student researchers report that they feel more confident in their ability to ask questions, feel as though asking questions is easier, and name differently the role and value of asking questions throughout the research process [1]. More specifically, the strategy has been applied in undergraduate engineering courses to stimulate curiosity and student engagement [5], and similarly has been found to also encourage divergent thinking for high school students [6]. Indeed, it seems as though question formulation is a critical skill for learners in the 21st century to develop [7], [8] so they may become more curious, self-directed problem-solvers and thinkers. In an effort to democratize access to this fundamental skill, most resources on the QFT are made available for free to download online.

1.1. Elements of the Question Formulation Technique

The QFT is comprised of a few essential elements. As a part of the first element, learners are first presented a Question Focus (QFocus), which serves as a prompt to elicit questions. Then, learners formulate their own questions on the prompt while following four rules for formulating questions:

- Ask as many questions as you can.

- Do not stop to judge, discuss, or answer any questions.
- Write down every question exactly as stated or exactly as it comes to mind.
- Change any statements into questions.

As they think about these rules, learners should reflect on what might be challenging about following them as well as how it may differ from the way they typically formulate questions. Learners will hold themselves and others accountable for following these rules as they respond to the QFocus for a set amount of time (usually about 4-7 minutes).

As a part of the second element, learners begin to work with and improve their questions. They learn about two different types of questions—closed-ended questions which can be answered with "yes", "no", or with one word; and open-ended questions which cannot be answered in such manner, as they require more of an explanation. Learners then review their list of questions and label their questions as "C" if they are closed-ended, or "O" if they are open-ended. Next, learners name the advantages and disadvantages of both types of questions, reflect on how the wording of a question influences the type of information it may elicit, and then proceed to change one of their questions from closed-ended to open-ended and one of their questions from open-ended to closed-ended.

In the third element of the QFT, learners begin to strategize on their use of questions. Depending on how questions will be used, the prioritization instructions may be tailored by the facilitator. For example, if the facilitator is hoping students will use their questions to guide research, the instructions may be "choose the three questions you are most interested in using to guide a research project." After prioritizing, learners think on their rationale for why they prioritized certain questions keeping in mind the QFocus, how many questions they asked in total, and where their priority questions landed in the sequence of all their questions. Learners are now ready to use these questions flexibly depending on the next steps of the learning process—whether it be for research purposes or otherwise.

In the final element of the QFT, learners reflect on what they learned, how they learned it, and what they are thinking about differently after having gone through the process.

The previous elements are the core components of the QFT. With this said, the strategy is flexible and creates the space and opportunity for educators to tailor the strategy to better support the teaching and learning objectives. In this vein, an adaptation of the QFT, the QFT for research, was developed with funding from the National Science Foundation to design a strategy to help researchers ask better, more transformative research questions. This adaptation has been used by undergraduate researchers, graduate researchers, and faculty alike, and many stakeholders find that it creates a discrete, eminently practical process through which researchers can arrive at new, better questions.

The QFT for research adaptation inserts a few key elements. First, researchers work to identify possible areas of interest, then name potential research topics, and finally prioritize the one research topic on which they would like to ask questions (this serves as the QFocus). Rather than experience the QFT as a group process, the research process is typically facilitated as an individualized experience which learners are simultaneously guided through. In the second

element, after changing questions from closed-ended to open-ended and from open-ended to closed-ended, researchers have the opportunity to review their list of questions and think on whether they would like to adapt, revise, or edit any questions they have created thus far. They then add these new questions to the bottom of their list. Later, in the third element, after prioritizing three questions, researchers select *one* priority question on which they would like to ask more questions. They then go through a brief period of question formulation on the priority question they identified, further refining it into a salient question. Researchers then have more opportunities to work with and refine their questions, after which they identify three questions they are glad they asked as well as three questions that may help to advance their research. Researchers conclude the process having produced a research agenda, ample guiding questions to support their inquiry, and an experience in honing a quintessential skill for research.

2. Motivation

Oregon Institute of Technology's motto is "Hands-on education for real-world achievement." Courses with a laboratory component provide an opportunity for hands-on education. The real-life application of the content covered in courses with no laboratory component is provided by different learning experiences. The purpose of this study was to assess the effectiveness of the QFT as a strategy to promote application, analysis, and evaluation in upper-division engineering courses.

3. Methodology

Two class sections (Group 1 and Group 2) of Renewable Energy Engineering students were assigned a term paper at the beginning of the quarter. The topic of the paper was selected using the QFT in two different ways. Students were given minimal instructions on how to develop the paper to both give students the opportunity to drive their own research and to understand the effect of the QFT on student learning throughout the term. A series of checkpoints were facilitated throughout the term to monitor student progress and create inflection points for feedback, from both students and faculty. The specific methodologies utilized in each group are as follows:

Group 1 was a class of 11 junior students taking the course "Materials for Renewable Energy Applications." These students were introduced to the QFT through a class exercise (Appendix A), utilizing the title of the class as the Question Focus. Students were divided into three subgroups, A, B, and C, of three to four students to generate questions. Each subgroup selected their priority questions; then the whole class classified the priority questions according to common themes. As a follow-up, students were assigned homework giving them an opportunity to utilize the QFT on their own to generate questions that would be answered in a paper on the use of materials in a specific renewable energy application.

Group 2 was a cross-listed course titled "Production of Biomass and Biofuels." There were seven undergraduate students and four graduate students in this class. One of the undergraduate students was also enrolled in Group 1. The adapted version of the QFT, the QFT for research (Appendix B), was introduced to the class to develop a topic of research throughout the term on

the subject of biomass conversion technologies. Due to time restrictions, only steps 1-5a were covered in class. Students were asked to complete steps 5b-7 as a homework assignment.

Students from both groups periodically reported on their progress (see Figure 1). One of the first checkpoints was the submission of a table of contents and a timeline for their final papers. Students were then asked to report on their progress according to their timeline at some point during the term; at a later point students submitted their progress for peer review. Although the calendar for each group was different, the experiences in one of the groups allowed for improvements to the checkpoint assignments in the other, and vice versa. The final papers for both groups were submitted during the week of final exams. The final paper and all checkpoint assignments were submitted via Canvas; the Turnitin tool was utilized to monitor plagiarism. The one student enrolled in both Group 1 and 2 developed their papers on the same topic, focusing on application of materials for the first paper and biomass conversion technology for the latter.

4. Results

4.1. Course-level results

The questions generated during the in-class exercise for Group 1 are reported in Appendix C. These questions allowed the instructor to establish a baseline of student knowledge, starting with the question: “What is ‘Materials for Renewable Energy Applications’ all about?” and concluding with: “What constraints should be considered when selecting materials?” At the beginning of the exercise some students generated questions unrelated to the question focus, e.g. “To be or not to be?” or “What kind of material properties are needed for a space elevator?,” however these questions were not selected by students during the prioritization process. The categorized list of priority questions was revised during the last class of the term; students were able to either answer the questions related to the properties of materials in renewable energy applications, or to identify which ones were beyond the scope of the course, e.g. “How pollutant is the extraction/production of RE materials compared to fossil fuels?”

The timeline prepared by the students at the beginning of the term was more aspirational than organizational. It was observed that students with more detailed timelines were the most likely to stick to their plan of progress, at least partially.

The papers from Group 1 were, as expected, focused on applications of materials in several energy or renewable energy technologies, e.g. batteries, fuel cells, geothermal energy, solar panels, heat exchangers, transmission lines, bioethanol production, energy conservation materials, and wind turbines. Students in Group 2 developed their papers on the topic of biomass conversion technologies, including regional assessments, lignocellulosic biomass fermentation, pyrolysis, anaerobic digestion, landfill gas capture and use, biodiesel, hybrid power systems, and biofuels as energy storage, Several of these topics were covered in class, however student papers developed some of these topics with much more depth, or considered applications not covered in class. Figure 2 shows the topic development for the one student who was enrolled in both Group 1 and Group 2. Although the general topic is the same, the approach to each paper was different. The Turnitin software did not detect plagiarism in student submissions.

The submitted term papers demonstrated the outcomes of a customized learning experience. Each paper was originally developed using the questions generated by each student, although in some cases the final table of contents deviated from their original projection. Students were asked to self-report if the final papers answered their original questions, or to what extent they felt their papers deviated from them (Table 1). Only two students reported no deviation from the original question. The rest of the students equally reported that their paper either answered the original question and had evolved into new questions, or that it had completely deviated from the original questions (Figure 3). It is worth noting that students from Group 1, who experienced the QFT as a group exercise, reported overall more divergence of the original questions. Students from Group 2, who worked with the modified version of the QFT, the QFT for research, reported greater consistency with their original questions and scope of inquiry.

The students were asked to rate their experiences using the QFT in summative questions as part of the course evaluations. The course evaluation scores out of a possible 5.0 total points were 4.7 and 5.0 for Group 1 and 2 respectively. It is worth noting that the Production of Biomass and Biofuels course taught to Group 2 is a new offering in the BS and MS Renewable Energy Engineering curricula. The relevant learning objectives for both classes list the following as either essential or important, as selected by the instructor: "Gaining a basic understanding of the subject (e.g., factual knowledge, methods, principles, generalizations, theories)", "Learning to *apply* course material (to improve thinking, problem solving, and decisions)", and "Developing specific skills, competencies, and points of view needed by professionals in the field most closely related to this course." The rest of the learning objectives were considered minor. The course evaluation revealed that students highly rated two comparatively minor learning objectives: "Learning how to find, evaluate, and use resources to explore a topic in depth" and "Learning to *analyze* and *critically evaluate* ideas, arguments, and points of view" in addition to the three essential or important objectives identified by the instructor (Table 2 and Table 3). As reference, student rating for the Materials course last taught by the same instructor are presented as point of reference. At that time, the course evaluation rating was 3.8/5.0. The student ratings are considerably higher in comparison to this previously taught Materials course.

The course evaluation included an additional question "Has the term paper contributed to your learning the course material? Why or why not?" to evaluate the effectiveness of the term paper towards student learning. Anonymous student responses are listed in Table 4. From the total 22 students enrolled in both groups, 20 (90.1%) answered this question. Among those who responded, 90% (18 students) reported that the term paper had positively contributed to their learning of the course material, and almost half of them (9 students) mention terms related to "deeper learning" or "independent learning." The two students from Group 2 who did not answer this question reported that their paper was not completed by the time they submitted their course evaluations. Course evaluations were due six calendar days before the paper for Group 2.

4.2. Student-level results

4.2.1. Students Name the Value of the QFT

Overall, students were overwhelmingly positive in their views on the strategy. One student said that they were, “excited to have some of these questions answered during the course!” and another shared that “this was fun and hard for me. It required some deeper thinking, so answers weren't to [sic] basic or very difficult.” Others “found it to be a useful tool overall,” “found it really useful, more so than I would have thought!” and another believed that ‘It’s definitely an interesting approach. I did enjoy this method because it helped me ask more questions regarding the class.” For one student, this was an eminently practical strategy and that they “would definitely use this technique again. The technique almost forces you to look at the subject from many different angles.” For students, this strategy helped stimulate engagement, foster deeper thinking, and was a specific strategy they could envision using in the future to support their own work. Students spoke to how the QFT created a collaborative space to learn from one another, reflect on how their question formulation skills and thinking on the role of questions changed over the course of the experience, and they connected the outcomes of their research paper to their original questions.

4.2.2. Students Identify the Role of Collaborative Learning

Through the collaborative group QFT, learners had the opportunity to learn from one another while experiencing a variety of perspectives. For example, one student found that, “It’s definitely an interesting approach…[it] also helped me learn from other students and see their point of view of things.” Another shared that, “I enjoy being able to share ideas and help generate with a group.” Indeed, the thinking of students is made visible through this collaborative work, and one student believed that, “seeing everyone's ideas posted on the white board was a nice way to see how we all thought.” Yet another student wrote that, “from a personal perspective, it helped me start thinking deeper about materials from a micro/macro perspective and gain perspectives from my peers that would of [sic] never crossed my mind.” Not only was this student thinking differently about the content and area of focus, they also recognized that their thinking was informed by the unique insight of their peers. One other student found that, “talking within groups is also a good way to discover thoughts and ideas that you may not have otherwise thought of.” Through collaborating and learning with one another, the class established an inclusive, collaborative spirit from the onset of the research process. They recognized that not only can they learn from the professor, but they are also resources to one another, and their diverse perspectives may help to inform the direction of their thinking and researching.

4.2.3. Students Develop their Ability to Formulate Questions through a Discrete Strategy

The QFT created the space for students to hone and develop their question formulation skills. One student reflected that, “it was a good experience to have a group together that was able to ask questions that would then lead down a path of similar questions with key differences. Looking back at the questions and selecting some to rephrase from open to close or close to open was also good because it allowed us to rethink what the heart of the question was. With an approach that has a wide beginning then narrowing them down later it [sic] gave us better results.” Not only does this student identify the discrete outcomes of the strategy, they also name how they better appreciate that the phrasing of a question may influence the information it elicits. Another student similarly found this exercise to be helpful, sharing that, “Reversing the open and close ended questions was an interesting way to see how information can be interpreted. You can

almost manufacture an answer by carefully wording a question, if that makes any sense." This student names that the answer (or relevant information) to a research question is directly related to the question which is posed. This same student also found that, "after reading over the questions it was apparent that some of our questions were repetitive but it made us think about a broader spectrum of topics overall. It was like a new way of starting a paper. Instead of writing down everything that comes to mind in a jumbled mess, ask yourself questions that seem relevant to what you are trying to write about." For this student, the strategy created the space and the framework to be more deliberate and structured in their question formulation as to better support their launching into the research process.

Another student agreed that the QFT provided them the space to do this type of thinking via question formulation while piquing their interest. "Writing down my stream-of-conscience thoughts really helped me to brainstorm effectively and quickly. It's an impressive exercise for the brain to be able to pick apart its own scattershot ideas and categorize them. I really like the process. It also helped me to confirm that I truly have a big interest in the subject because [sic] all of these questions came a real desire for answers." This student recognizes the space which was created to do rigorous, efficient thinking, and they also name how from these questions an eagerness for diving into the research process has been affirmed. Questions do not just inform the answers which are investigated, but they can also shed light on the need to ask other questions. One student suggested that, "just the act of brainstorming questions led to more questions. It really helped me understand not only what I didn't know about the subject, but also what I wanted to know." This capacity to know what they do not know—what Stuart Firestein [9] refers to as ignorance, is at the heart of research and inquiry. In order for researchers, scientists, and learners to forge ahead, they must first recognize what they know just as well as what they do not yet know. One step beyond this, they must recognize what others know, and what has yet to be discovered or better understood by researchers and society writ large.

4.4.4. Students Connect Initial QFT to their Research Outcomes

Some students learned that even upon completing their research paper there were more questions and ideas to be explored. One believed that despite "feel[ing] like I got very detailed and accurate answers to all of my questions… I learned that there is so much more information about [solid oxide fuel cells] than I could discuss in my paper. While I focused on one composition for each component there are so many more options." One student saw alignment between their initial questions and final paper, as well as how they were able to drill down further than the original framing. "The paper didn't deviate much from the questions but writing the paper made me ask myself even more questions which made me write more in depth." Another was nimble in their approach, "all questions were answered, just not how I first envisioned them."

Not all students' final questions aligned with their initial experience. One student said that, "my paper did not match my original questions at all. My overall topic changed completely as I was researching my questions." For this student, initial research informed the need to shift their focus, and they named this when they said, "questions you have before you know anything about a subject change as you learn about it." Others were flexible and identified that they needed to narrow the scope of their work as they began the research process: "I also learned the importance

of having a narrow focus on a subject. My questions were broad and led me to try multiple ideas for my paper before finally choosing one. I will definitely try to be more specific in the future."

5. Discussion

5.1. Introduction of QFT as in-class exercise (Group 1) compared to as homework assignment (Group 2)

The depth of the initial reflections after experiencing the QFT was stronger for Group 1 than Group 2. Some students from Group 1 who were dissatisfied with their topic were able to reproduce the QFT exercise as late as in week 7 of the 10-week term to select a new topic. The quality of these late-developed papers was comparable to the ones of students who worked on the same topic since the beginning of the quarter. It appears that Group 2 students had more issues finalizing the QFT on their own since they did not have the opportunity to go through the whole experience at least once as a group. In Group 2 the quality of submissions on the completion of the QFT was varied. Perhaps an ideal scenario would be to use the QFT in class, as a group, followed by a facilitation of the QFT for individual work on a different day. This approach would give students both the opportunity to learn from one another while experiencing the strategy in-full, and the exposure to the discrete QFT for research to use on their own later.

5.2. Use of simple or modified QFT (Question Formulation Technique vs Question Formulation Technique for research)

The QFT was a very effective way to establish a baseline theme when students had to develop an individual study on the topic. In the case of Group 1 the topic was on how properties affect the use of materials in a specific renewable energy application of their choice.

The modified version of the QFT, the QFT for research, is useful when learning is more individualized and the topics chosen by the students do not have to follow a general development line, as it was the case of Group 2.

In all cases, both applications of the QFT are effective strategies to personalize the learning experience. Students were empowered to choose how they wanted to apply their learning and newfound knowledge, and which direction they wanted to expand and deepen their learning. Students developed ownership of their own education. Even for students who switched topics, it was a source of relief to know that they could always choose a topic of their interest within the general theme of the course.

A secondary effect of the use of the QFT was the increase in student participation in class. This was particularly noticeable in Group 1 where the papers had closely related themes to the subject matter of the class. In some cases, students were studying in advance some of the class topics. By the time we touched on those topics as a group, they were able to speak from the experience of their own research about the relevance of those topics and their implications and applications. Lectures became a dialogue with multiple participants, further shifting the onus of learning from faculty as keeper of knowledge to a more learner-centered classroom environment with diffuse experience and knowledge.

5.3. Student accountability

Multiple checkpoints allowed the instructor to follow the progress of the students and motivated students to remain on target with their project timeline. These checkpoints are detailed in Figure 1, with the week number of when that checkpoint occurred for each group enumerated in the corresponding row. Despite these checkpoints, some students demonstrated a proclivity for procrastination and did not take full advantage of the benefits of the QFT. This fact can be observed in one or two of the checkpoints, where a small subset of students reported no progress or did not respond.

According to both student feedback and the few absent responses, it is apparent that many of the students are still developing the time management skills necessary to stay on task for a term-long, student driven project. More frequent or weekly checkpoints have the potential to provide more insight into the detailed process of the QFT. Further, more checkpoints could also create more accountability measures to better ensure a workflow that will result in more refined, timely final projects developed by students in both groups. Implementing this into the next application of the QFT with a new group would likely take the form of weekly reports and discussion boards that would be taken into consideration for participation credit.

5.4. Effect on plagiarism

The QFT demonstrated to be an effective way to discourage plagiarism, since each student worked on a very personalized assignment from the beginning. Even papers on the same topic had a different approach according to student academic background and interest. For example, three students from Group 1 submitted papers related to photovoltaic (PV) energy with the following titles:

- Materials component analysis: Photovoltaic panels
- Fundamentals of crystalline silicon solar cells
- Properties of materials used for solar PV cells

Four students from Group 2 submitted papers on biodiesel with the following titles:

- Algae as a source of biomass and biofuel
- Comparing saturated and un-saturated fatty acid impacts in triglyceride oils on transesterification process that characterize a biodiesel product
- The future of biodiesel production using palm oil in Indonesia
- Biodiesel production process alterations

In all cases, the level, depth, approach, and examples found in all these papers were vastly different from each other. In each paper, there was an element of originality. It was observed that students with weaker backgrounds utilized the paper as a tool to reinforce fundamental concepts that allowed them to reach higher level analysis. Students with strong backgrounds produced papers covering many additional aspects beyond the content covered in class.

5.5. Peer review in the QFT

The QFT can be utilized as a strategy for formative evaluations. The QFT throughout the term can be used as a continuous improvement process in student learning. Multiple checkpoints leading to student accountability do not necessarily have to represent an additional workload for the instructor. Constant and varied peer review activities with detailed instructions provide students with multiple sources of feedback that they can choose whether they want to incorporate. Students are most likely to accept the feedback if it is coming from a peer. Feedback from faculty is often seen as an imposition rather than as a suggestion for improvement, and it can be received with resistance or fear of not having submitted a perfect assignment. Peer review takes this stress away and allows students to focus on their learning. As an example, the student enrolled in both groups shared their draft in week 8 to their peers in Group 1. The peer reviewers, independently, noted that this paper did not emphasize enough material properties. The student incorporated the recommendations as it is shown in the final paper layout reported in Figure 2.

5.6. Effect on student learning

The use of the QFT was a solid starting point for student papers, however, as more than 90% of students noted, the final product deviated from the original questions. This was not observed to be a problem in the learning process, rather as a refining mechanism that allowed the papers to evolve into more sophisticated products. Most students whose paper deviated from the original questions reported that the original questions were either no longer relevant, they did not find enough pertinent information, or they chose to follow the natural flow as the paper developed, either expanding or narrowing the focus of the paper compared to the original questions.

Student ratings and answers to the additional question in the course evaluation indicates that the use of the QFT throughout the term may have contributed to the development of higher cognitive skills according to Bloom's taxonomy. One question in the final exam asked students what they had learned from their paper. The purpose of this question was evaluative; however students were made aware that the weight of this question would not have a strong effect on their final grade, in an effort to collect information on the main ideas they remember instead of creating a stressful situation where students could be making up answers. All students were able to answer this question expanding concepts studied in class (Table 5).

5.7. Effect on course evaluations

In both cases the course evaluation results were very positive (Table 2 and Table 3). Students' feedback comments lead us to believe that the high ratings in the course evaluations were due to the implementation and follow up throughout the term of the QFT. The use of the QFT as a strategy to improve students' learning experience can be reflected in improved course evaluations by engaging students in a meaningful and personalized way, as was the case of the course taught to Group 1. The QFT can also help instructors when implementing new courses, as was the case of the course offered to Group 2.

6. Conclusion

The QFT was demonstrated to be a robust strategy to develop higher order thinking skills, collaboration skills, and to facilitate student-centered, independent learning and research. The present work focuses on Renewable Energy Engineering topics, but the methodology can be applied to Engineering education in general, and in disparate disciplines and subject areas. Breaking down a long-term goal (e.g. term paper) into frequent and periodic deliverables enhances student's accountability, confidence, and learning skills, while also mitigating plagiarism. Students' overall view of the cultivated learning environment is well represented by the positive influence on course evaluations.

It is advisable to make students familiar with the strategy during a class period before asking them to use it on their own as starting point for their own learning. There were no observed variations in approach between undergraduate and graduate students that are exposed to the QFT for the first time. The collaborative QFT was effective in a course with tighter course objectives. The QFT for research, although it was developed specifically for research, proved to be practical for a course that provided a myriad of paths to meet learning outcomes.

The application of the QFT presented in this work centers the learning experience on the student. Except for setting up checkpoints, where peer-review can play a very significant role, the QFT does not represent a heavy additional load to the instructor. In fact, it is a simple approach that has many benefits to the learning experience in general. It can effectively shift the onus of learning to the students as it fosters not just a collaborative and intellectually curious classroom that more colleges and universities are seeking to cultivate, but one in which students can drive their own innovative yet focused research.

7. Limitations

One limitation of this study is that it has yet to examine the learning outcomes as compared to those in other courses that have not integrated the QFT. For example, more could be understood by comparing the QFT between courses, and between different samples of students (both within and across colleges and universities). While we have term papers from students in previous courses that did not experience the QFT, we have yet to compare the quality of these terms papers as compared to students who experienced the QFT. Future research and analyses may benefit from multiple faculty using the QFT and comparing student outcomes with faculty who do not incorporate the QFT into their pedagogy. We invite the opportunity to think and learn with other educators and researchers who might like investigate how the QFT for research can support student research. There is so much to learn about how the strategy can support *all* learners from different institutions around the country and world. Further, it is possible that other inquiry-based approaches may produce similar student and course outcomes, and more research may help to define the unique contribution of the QFT to student achievement and learning.

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Tables and Figures

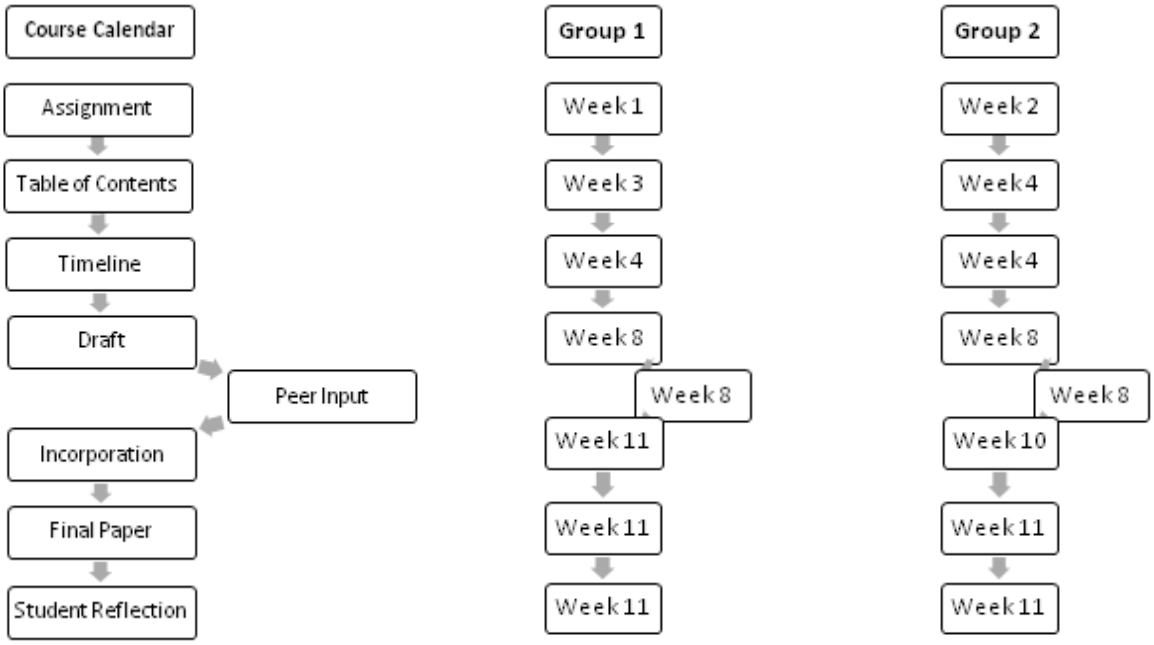

Fig. 1. Checkpoints corresponding to each Group's specific course calendar

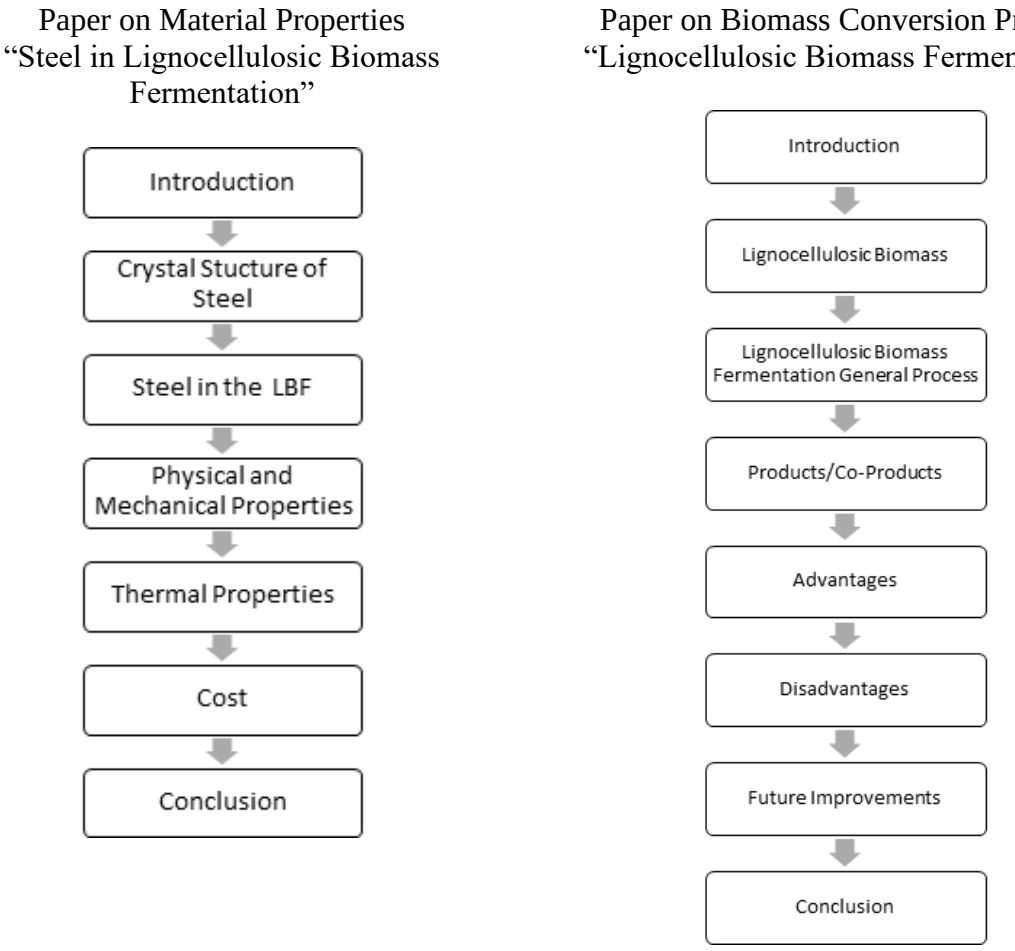

Fig. 2. Example of topic development for a single student enrolled in both groups for each one of their papers for Group 1 (left) and Group 2 (right).

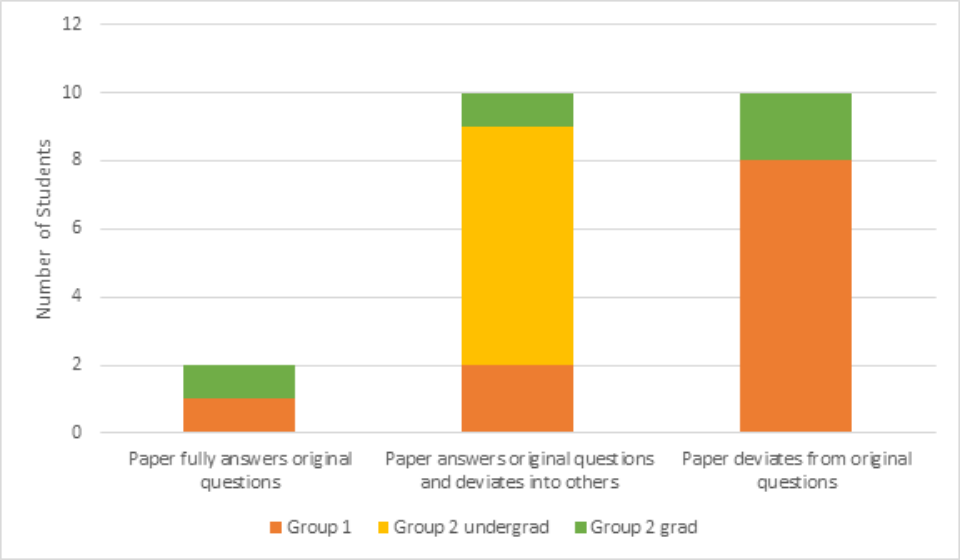

Fig. 3. Comparison of paper versus original questions as self-reported by students.

Table 1. Student responses to self-reported question "Compare the current version of your paper with the original questions developed on week 3. How is the paper answering your original questions? How did the paper deviate from the original questions?" Students are listed by their group (1 or 2) and classification (U for undergraduate, G for graduate). Answers are unedited.

Student	How is the paper answering your original questions?	How did the paper deviate from the original questions?
2U1	The topic of my paper has indeed been influenced by those original questions. It has generally been tailored to answering the questions I decided base my paper on.	There were many questions originally developed and not all of them have stayed relevant as I've worked on my paper.
2U2	Therefore, I am still using more of my original questions of how biomass compares to other renewable energy sources in Hawaii and its pros and cons, but instead of just focusing on just one type of biomass, algae, I decided to make it broader since there is more information on the biomass usage in Hawaii as a whole.	My original questions developed on week 3 are a little different from the questions that I am answering in my current paper. I originally planned on writing about specifically algae as a potential renewable energy source to help Hawaii achieve their Clean Energy Initiative. However, when I started researching more about this potential topic, I noticed that there wasn't too much information and reliable sources that would help me write this paper. Thus, I decided to make my topic less specific and just focus on biomass and biofuels as a potential competitive renewable energy source that will be a key played in Hawaii's Clean Energy Initiative.
2U3	My original questions were inadvertently answered through my research	however my paper essentially does not follow my original timeline/table of contents at all. During the writing process, my paper and topics developed a natural flow that deviated from my original questions.
2U4	Some of my original questions were: How do you determine energy density? Can biomass be use in sequence with a battery for storage?	After going through various lectures from the class, the paper has opened up to more topics such as energy densification and torrefied biomass. In addition, there are different types of batteries explained in the paper. The paper has also evolved into writing more about biofuels. The paper is also including the topic of how the energy

	The paper, at its latest stages of development, has gone over how a generator can be put into series with a motor to convert heat energy into mechanical energy which in turn can provide the energy for a generator to wind up and store that energy as an electrical potential. The potential electrical energy charges up a battery. In addition, there are carbon-based materials that improve batteries Energy density, in terms of biogas, is characterized by what type of starting material is used. The heating value, which is the heat released during combustion of fuel, relates to the moisture content as well as the impurities in the fuel itself after different processing. For example, if there is less sulfur content then the material is more energy dense.	market is expanding, which was not one of my original concerns. Battery material composed of biomass is used to improve its material strength and energy density.
2U5	I have included the more focused questions I had developed in the body of the current version of the paper (submitted today) as a frame of reference. As I am still compiling research, I have not had a chance to address all of my questions, but the main ones are in the process of being answered. In particular, the recent innovation in pyrolysis technology is catalytic pyrolysis, so I am discussing what that is, what catalysts are being used, and what the effects are to the products of pyrolysis, with bio-oil as the focal point. The use of catalysts is making bio-oil more useful for fuel purposes, answering the big question of what the implications of this technological advance are. Also, I have been able to a quick summary of companies using pyrolysis technology who are driving to make it a more viable energy resource on the national and international scale.	I have not spent much time researching those who are against the use of pyrolysis, because I no longer think that it is important in the scope of this paper. I am also considering to talk less about all the different types of pyrolysis reactors to focus more on catalytic pyrolysis. I suppose you will which direction I go within 48 hours!
2U6	My paper does answer most if not all of my original questions. Most of those questions are answered in hte introduction and explanation of the anaerobic digestion prrocess.	My paper deviates from the original questions by detailing the cleaing process of biogas, by looking at benefits of biogas cleaning, and by considering cost benefits.

2U7	The current version of the paper is a broad overview of the topic, with certain specific areas broken down. This is basically precisely how the question exercise progressed. I asked some basic questions and then narrowed down a couple of topic areas to focus on. The rapid-fire question gathering was a unique, and I think, helpful way to quickly choose a topic for a research paper.	The process can otherwise be too open-ended and vague.
1U8		The paper didn't deviate much from the questions but writing the paper made me ask myself even more questions which made me write more in depth.
1U9		I've had to narrow my focus questions so I could more accurately evaluate the component I was studying. The focus just added to my understanding of SOFCs and their components.
1U10	Other than this, I feel it did a decent job of answering my questions, but my questions were more broad, so it wasn't hard to discuss them.	It deviated away from the questions by only focusing on specific solar cell types and costs.
1U11		My original plan involved more variety in what materials I looked at but due to time and difficulty finding research I spent more time talking about specific materials instead.
1U12	My paper didn't deviate from my original. It made clear to me why aluminum overhead conductors are popular and why the expansion of HVDC conductors are slow.	
1U12		The paper was more specific than my original questions. And I broadened the paper from the questions to include introductory info and other insights.
1U13	The only original question my paper answered was "What is Lignocellulose Biomass Fermentation."	Other than that, my paper was about 98% deviated from the original questions.
1U14		The paper deviates from my initial QFC by focusing so much on the elementary fundamentals of semiconductors, rather than honing in on the design features of residential solar panels.

1U15		My paper was originally focused around the physical properties of CTL but grew to incorporate the environmental effect of CTL vs concrete/steel. It also spoke on current projects in North America that are using this technology. I originally wanted to compare the difference in cost between CTL and concrete but found it difficult to find material that showed how a single project would have cost w/ CTL vs concrete.
1U16		Originally I wanted to also focus on financial costs and environmental impact of the materials discussed in my paper. However, I decided to focus more on the material properties. I decided to focus more on structure, conductivity, and the photovoltaic effect because after these lectures I became more interested in their impact on solar PV cells.
1U17		My paper deviated slightly in that I went into great depth on the different composite compositions that I forgot to discuss the great ecological impact of these material decisions.
2G1	The paper followed my questions pretty closely.	However I combined and rearranged some sections. The question "what are the different uses of algae?" I spread throughout the paper, mentioning uses such as dry biomass and creating bio diesel when I talked about the harvesting and refining processes.
2G2		When comparing the questions first established during week three, the paper did deviate a little bit more towards a density, viscosity, combustion, efficiency, emission, and cold flow type of route. I had anticipated the research accumulated regarding differences between saturated and unsaturated fields would have lead to a biodiesel yield based topic. This is because I ran several experiments with varying free fatty acid concentrations and found I always

<table>
<tr><td></td><td></td><td>obtained a higher yield of more ASTM appreciable fuel when using oils high in unsaturated fats. Instead, I found out that saturated and unsaturated fatty acid chains are more like a biodiesel balance, trying to find the most preferred balance of cold flow, and combustibility characteristics. One thing I did find interesting toward the end of my research was the significance of oleic and linoleic acid groups that contain cis-cis bonds and categorize poly-unsaturated fatty acid concentrations. The cis-cis configuration of the hydrogen on one side of the carbon double bond actually weakens the intermolecular forces by dipole configurations that actually produces fuel that seemed more efficient then single bonded saturated fuels, but shared the same cold flow characteristics as a unsaturated fatty acid compound. Also learning techniques to break double bonds and change the acidic concentrations of existing oils was unexpected.</td></tr>
<tr><td>2G3</td><td><table>
<tr><td>Questions</td><td>Remarks</td></tr>
<tr><td>Is there any ecological issue related to biodiversity?</td><td>It is discussed on the paper although the main issue is not biodiversity but the human population that affected by lands opening for palm oil plantation</td></tr>
<tr><td>Is it worth to convert the land for palm oil plantation?</td><td>It is shown on the paper by giving the economic advantage of palm oil export</td></tr>
<tr><td>Why is palm oil taken as a priority?</td><td>It is shown on the paper</td></tr>
<tr><td>What is the technological advancement today</td><td>This question is discussed in a very general way</td></tr>
</table></td><td></td></tr>
</table>

<table>
<tr>
<td></td>
<td>
<table>
<tr><td>regarding biodiesel production from palm oil?</td><td></td></tr>
<tr><td>How competitive is biodiesel compared to fossil fuels?</td><td>It is mainly shown the competitiveness of biodiesel from the perspective of environmental advantages</td></tr>
<tr><td>How is the competition between palm oil for biodiesel and for food?</td><td>It is shown on the paper</td></tr>
<tr><td>How is the comparison between palm oil feedstock and other feedstocks?</td><td>It is shown on the introduction</td></tr>
<tr><td>What is the economic advantage of producing biodiesel?</td><td>It is shown on the introduction</td></tr>
<tr><td>How is the support from the government?</td><td>It is discussed specifically on the body</td></tr>
</table>
All of the questions are answered on the paper to a different scale of analysis. The paper does not deviate at all from the original questions. They provide a possible direction of the method being used to develop the whole paper which finally fixed on SWOT analysis.
</td>
<td></td>
</tr>
<tr>
<td>2G4</td>
<td></td>
<td>My original questions we asking about what types of processes and equipment are used in the production of biodiesel. What feedstock and chemicals are used to produce biodiesel? My paper no focuses on the different aspects of the transesterification process that can be altered. The different types of catalysts used and how these catalysts can only be used with certain feedstock. My paper now also looks at different ways to intensify the process so more biodiesel is produced in a shorter amount of time.</td>
</tr>
</table>

Table 2. Five of the thirteen relevant learning objectives evaluated for Group 1.

Relevant Learning Objective	Importance Rating	% Students Rating 2013	% Students Rating 2019
Gaining a basic understanding of the subject (e.g., factual knowledge, methods, principles, generalizations, theories)	Essential	81	100
Learning to *apply* course material (to improve thinking, problem solving, and decisions)	Essential	63 (Important)	82
Developing specific skills, competencies, and points of view needed by professionals in the field most closely related to this course	Important	63 (Essential)	100
Learning how to find, evaluate, and use resources to explore a topic in depth	Minor	68	82
Learning to *analyze* and *critically evaluate* ideas, arguments, and points of view	Minor	38	91

Table 3. Five of the thirteen relevant learning objectives evaluated for Group 2.

Relevant Learning Objective	Importance Rating	% Students Rating 2019
Gaining a basic understanding of the subject (e.g., factual knowledge, methods, principles, generalizations, theories)	Essential	100
Learning to *apply* course material (to improve thinking, problem solving, and decisions)	Important	100
Developing specific skills, competencies, and points of view needed by professionals in the field most closely related to this course	Essential	100
Learning how to find, evaluate, and use resources to explore a topic in depth	Minor	90
Learning to *analyze* and *critically evaluate* ideas, arguments, and points of view	Minor	80

Table 4. Anonymous student responses to additional question in course evaluation “Has the term paper contributed to your learning the course material? Why or why not?” Answers are unedited.

Group (Responses/ Enrollment)	Student responses
Group 1 (11/11)	• Yes it have, • Yes, it helps us to focus on analyzing the actual properties of practical applications. • The term paper has encouraged more independent learning and reading, which is overall good practice for continuing education. • It has helped with the understanding of a specific field though having such a large choice of topics can lead to difficulties choosing one that can increase knowledge in all fields. • Yes. Focusing on a single technology really helps you hone in on material properties and how important they are for all engineering applications. • The term paper helped me understand the choices that engineers/system designers need to make when designing devices based upon material properties. • Yes. It has caused me to think of the different properties to take into consideration when doing design analysis. It has helped me in other classes by making me think of all the components I need to take into consideration. • Yes, it forced me to look in depth to the concepts and apply them to a real scenario • Yes, I find that research papers help me with learning material more on a topic that I find interesting. • Yes, I've learned the significance of the subjects taught in this course to industries I'm interested in working in. • I have learned so much about the subject Of my paper and it was one Of the most fun paper to write just because Of how much I have learned from this class. The topics that we learned in class helped me delve a lot deeper into the subject
Group 2 undergrad (7/7)	• Yes, because I have able to dive deeper into the topic of pyrolysis and find out what has been happening lately with this technology. • Yes, it offered an opportunity to dive deeper into modern research of biomass-related practices. • It has provided an avenue for a deeper exploration of a topic. I deviated from my initial questions because as I searched, I gained a better understanding of the subject and formulated more interesting questions. • Yes, because it helped me understand the process and the different types of biomass and biomass production methods. In addition, we also learned about the different products and uses for biomass, thus, helping me write this paper because I know the important topics to cover. • Not really. Like many students, most of my energy is spent in just trying to keep up. This unfortunately means that the vast majority of the term paper doesn't get completed until shortly before its due. • Reading articles related to the subject of the paper has helped increase my overall knowledge of biomass systems and

	processes. • NO, because I haven't done it yet.
Group 2 grad (2/4)	• I would say so. It let me go more in depth into a topic I was interested in, which consequently lead to learning more about bioenergy in general. • Yes. It encourages students to gain more knowledge out of regular class session

Table 5. Student answers to exam question: “What did you learn through the process of writing your paper?” Answers are unedited.

Group (Responses/ Enrollment)	Student responses

Group 1	• I have learned:
	  • How a possible graphene battery is created and future ways to improve on them.
	  • How to extract graphene from graphite and that improvements are yet to be discovered.
	  • More about Lithium ion batteries and its graphene hybrids.
	• I learned that there is so much more information about SOFCs than I could discuss in my paper. While I focused on one composition for each component there are so many more options. I also learned about some cool applications such as SOFCs in locomotives.
	• Through writing this paper I learned how solar panels properly work and the numerous parts that must work together in order for them to work properly. I also found new ways they are trying to increase the efficiency of solar panels with anti-reflective coatings, multilayer semiconductors, and even submerging them for temperature control.
	• No response
	• I learnt that many properties and components go into even a simple system. There are so many properties to take into account and there always is given and take when deciding what should be used.
	• I learned A LOT about evaporation generators, how they work, and how they could be implemented in a full-scale. I also learned it can be hard to find all of the properties of materials you are looking for when designing, so your own testing may be required! And importantly, how the materials used affects how the generator functions!
	• Time management is important. Questions you have before you know anything about a subject change as you learn about it. Next time it might be a better practice (at least for me personally) to write a little bit each week focusing on the topics covered that week during the course.
	• I learned so much about solar cells, for one thing. My research really covered a lot of ground and I only included a small amount of it in my paper. I learned about material fabrication techniques, data collecting, etc. I also learned the importance of having a narrow focus on a subject. My questions were broad and led me to try multiple ideas for my paper before finally choosing one. I will definitely try to be more specific in the future.
	• What I learned about CTL is that it is a promising new material that is beginning to see a lot of uses in the construction of multi-story buildings. One of the most interesting aspects of CTL is that the process of the material can fabricate sections of the building prior to shipping to the construction site. This speeds up construction time and allows the designer to make the building out of interlocking parts (like legos). CTL also acts as a viable method of carbon

	sequestration since the material is primarily carbon based and buildings typically have a long life span. You can also grow the base material (wood, trees) making sustainable* (only if proper measures are taken to ensure future resources). • This paper enhanced what knowledge I already had about the photovoltaic effect and energy band gaps. It also helped me connect optical properties to those subjects for better than I understood previously. After writing this paper I feel like I can see how the different properties relate in order to make use of semiconductors for PV applications. It also gave me perspective into the engineering approach for choosing materials in order to create devices. • I learned that there are many material properties being considered when a wind turbine is being designed. A vast majority of these material considerations are related to the materials mechanical properties. I learned about the importance of natural resonance frequency. I learned that there are serious efforts being put towards making blade materials recyclable.
Group 2 Undergrad	• I learned that biofuel power generation is an extremely effective generation method when used in conjunction with another renewable power source as part of a hybrid power system .The biofuel used can be adapted from the region where the system is located, making it widely applicable. The supplementation of power generation with other inconsistent sources like solar or wind reduce the total cost of biofuel needed. • Through the process of writing my paper, I learned more about the pros and cons of biomass and the specific reasons as to why biomass isn't as popular in Hawaii compared to wind and solar, but also why and how biomass can be incorporated more to help Hawaii reach their Clean Energy Goal. This also confirmed with what I learned in class about how Biomass/Biofuels really does depend on the location, the economy, politics, society, and what space and materials are available. It also confirmed my knowledge on the different conversion processes, their feedstock, their products, and their own pros and cons. • I learned that the questions you develop before you know any information about something change as you research that subject. I also learned that you cannot always find direct answers for your questions. In addition to that, I learned the importance of ethanol to the industry and how to derive it from plant material. • I have learned a lot about anaerobic digestion and the process of creating biogas. Creating renewable natural gas can produce heat to generate electricity, and that electricity can be used to power homes connected to the grid. I learned how the technical potentials coincide with economical potential when biomass is used. • I have learned, and am continuing to learn, as I finish my paper over the next 40 hours, about the recent technological advances in the pyrolysis industry. Namely, the same change seems to be catalytic pyrolysis, where metal and other types of catalysts are used in the pyrolyzers to lower the oxygen content of bio-oil, making it much more valuable as a fuel product. • On the whole, I enjoyed the exercises of the question improvement model. It gave me a sense of direction as I began researching on my topic , which at the

<table>
<tr><td></td><td>start was just the topic of pyrolysis (generally). By forcing us to think about the topic, it made the process of research somewhat easier, because I had arrived at several focal points before the onset of research. In the research process, however, the direction of the paper shifted slightly. I did not originally intend to focus as much on catalytic pyrolysis as a viable fuel source.
• One thing I did not learn, however, is how not to begin writing my paper sooner in the term. I have always been a procrastinator with papers, and it seems nothing has changed. It may mean that I sleep very little in the coming days, but I will finish the task, indeed.
• I learned the importance of economic potential for any given energy source but particularly anaerobic digestion. I found a case study from Louisiana where a parish and the state investigated an AD biogas plant for energy production and waste disposal. They found that while plenty of feedstock could be sourced from Universities, schools, hospitals, and grocery stores. The cost of constructing and operating the plant would be greater than buying energy from conventional sources and buying land for a new landfill. They projected 20 year return on investment was around $1 million and both state and parish declined the project.
• I learned that writing research papers has always been a challenge for me and will continue to be so no matter how many times I do it. That being said, the process of question building and rapid-fire brainstorming helped me to narrow down a topic early on which is always a challenge for me. Landfill gas capture was something I knew nothing about previously and is an interesting resource that should be utilized.</td></tr>
<tr><td>Group 2
Graduate</td><td>• The question improvement model was one of the more important things I learned, it was incredibly helpful. When looking into algae as a biomass, I got an appreciation for the economic and spatial considerations that go into cultivating biomass. Even if a biomass has great energy potential, if too much or too little is grown, it cancels out any benefit. Additionally, I was able to learn more about oil extraction as the methods for algae are similar to methods used for oil seeds.
• I learned that decreasing temp, increasing temp, decreasing methanol, and increasing KOH in transesterification process = fatty acid chains to break bonds and convert to saturated fats.
• Characteristics can be manipulated by oil chosen based on sat % and at % most poly-sat need a reagent since bonds are so strong thy need to be broken to react.
<table>
<tr><td>Saturated Fats</td><td>Unsaturated Fats</td><td>Poly w/cis bonds</td></tr>
<tr><td>↑N</td><td>↓N</td><td></td></tr>
<tr><td>↑CN</td><td>↓CN</td><td>↑CN</td></tr>
<tr><td>↓Cold Flow</td><td>↑Cold Flow</td><td>Fdaf</td></tr>
<tr><td>↑Chain length bonds break easier</td><td>↑Density, more E to break bonds</td><td>From dipole configuration have high E density but break bonds easily by internal forces</td></tr>
<tr><td>↑Viscosity</td><td>↑Viscosity</td><td></td></tr>
</table>
</td></tr>
</table>

	• I learned to find a topic and develop them with the help of relevant questions. Finding resources in journals is also important to be learned during paper writing. By reading numerous papers that relate to the topic, I learned to develop my skill in critical thinking that guided the method and the organization of the paper. In addition, I learned to use the review from the peers and incorporate them into my paper accordingly. • I learned that there are multiple types of catalyst that can be used in the transesterification process. Also some catalyst can be used with higher FFA and water %. Not all process require a catalyst, creating biodiesel using supercritical process allows you to need a catalyst. There are ways to increase production and decrease the time required for production using microwaves, ultrasonic cavitation, and hydrodynamic cavitation. Also recycling the glycerol into the reactor can decrease the amount of alcohol you input into the reaction.

Appendix A

Utilizing the Question Formulation Technique to Establish Knowledge Baseline

Instructions:

1. Form groups of 3-4 students
2. Select a note-taker
3. Consider Question Focus: *Materials for Renewable Energy Applications*
4. Ask Questions Following Rules
    1. Ask as many questions as you can
    2. Do not stop to answer, judge, or discuss
    3. Write down every question exactly as stated
    4. Change every statement into a question
    5. Number each question
5. Categorize your questions as closed-ended [C] or open ended [O] (1min)
6. Improving Questions: Transform closed-ended questions to open ended questions. Transform open ended questions to closed-ended questions. (7 min)
7. Prioritize your questions:
   Which questions are more relevant for your learning process? (4 min)
8. Share your priority questions with the group and find common themes with other groups (6 min)
9. Reflection

Appendix B

Question Formulation Technique for Research (Question Improvement Model)

1. Identify research topic
    a. Write down some topics you may consider for research (1 minutes)
    b. Choose one topic you are considering for your research (15 seconds)
2. Produce questions
    a. Ask questions about the topic you chose (3 minutes)
        i. Follow the Rules for Producing Questions
            1. Ask as many questions as you can about your research topic
            2. Do not stop to answer, analyze, or judge questions
            3. Write down every question exactly as it comes to mind
            4. Change any statements into questions
        ii. Number the questions as you produce them
3. Work with questions
    a. Label your closed-ended questions with a "C" and your open-ended questions with an "O" (1 minute)
        i. Closed-ended questions are to be answered with a "yes", "no", or with a one-word answer
        ii. Open-ended questions require an explanation and could not be answered with a "yes", "no", or a one-word answer
4. Rework questions (1 minute)
    a. Change one question either:
        i. One closed-ended question and rework so it becomes an open-ended question
        ii. One open-ended question and rework so it becomes closed-ended.
    b. Add new question to the bottom of the list of questions.
    c. Do you have questions that you would like to rework?
        i. If so, rework questions, and add them to the bottom of your list
5. Prioritize and further explore
    a. Choose three priority questions that you are most interested in using to guide the research project. (1 minute)
        i. Star your three priority questions
        ii. Keep in mind the research topic that you identified earlier
    b. Choose one priority question that you would like to use as a guide for a research project
    c. Produce questions about your priority question
        i. Follow the rules
        ii. Number the questions as you produce them
6. Develop research question and agenda (1 minute)
    a. From all the questions that you have asked so far, choose:
        i. One question that you are glad you generated through the process
        ii. One question that may help you advance your research
7. Reflect
    a. What did you learn through this process?

Appendix C

QFT Responses to the QFocus: “Materials for Renewable Energy Engineering”

Students’ answers are unedited.

Group A

1. What are the most important materials in the solar field? (C)
2. What are the most important materials in the wind and geothermal field?
3. What are the most cost effective? (O)
4. What are the most used materials? (C)
5. How do you balance cost vs. practical effectiveness? (O)
6. What are the processes to determine if the materials are viable? (C)
7. Once developed, how do you get it established with building code etc
8. Are materials for RE different than for other non-RE things?
9. What other fields influence materials?
10. Are most RE materials organic or synthetic or etc?
11. What kind of research is going into making it more recyclable?
12. If plastic is best for something, does that counteract having RE source?
13. What is considered a material?
14. Is the renewable energy industry renewable?
15. Are living things considered materials? Algae?
16. Are there different “groups” of materials? Organic? Solid? Liquid?
17. How has 3D printing changed material research?
18. What constraints should be considered when selecting materials?
19. How important is application to the material?
20. What is the most promising upcoming material?
21. What schools/companies are doing most material research?
22. What are most important materials in solar field and why?
23. What makes a material cost effective?
24. What characteristics make materials most popular?

Group B

1. What is “Materials for Renewable Energy Applications” all about? (O)
2. What are materials for Renewable Energy? (O)
3. Will we focus on atomic structure vs. physical structure? (C)
4. Where are materials from? (O)
5. Just for structure or power efficiency? (C)
6. Are materials also for aesthetics vs. performance? (C)
7. How important is materials understanding vs. mechanical/EE engineering? (C)
8. What are the applications? (O)
9. What are the expensive vs. cheap? (O)
10. Most cost effective materials? (O)
11. What doesn’t work for Renewable Energy Applications? (O)

12. Which materials are ideal? (O)
13. What is implementation of ideal materials for Renewable Energy applications? (O)
14. Do some materials serve dual purposes?
15. Are domestic vs. outsourced materials better?
16. What is future outlook of supply of these materials?
17. What advancement has Renewable Energy materials seen?
18. What is cost analysis from zero to fully functional Renewable Energy science?
19. Are organic materials included in this category?

Group C

1. To be or not to be? (O)
2. What is a material? (O)
3. Why is solar used so much? (O)
4. What kinds of crystals are used in solar panels? (O)
5. What are the most cost efficient materials for semiconductors? (O)
6. With the wave of plastic industry, how will it affect the renewable energy industry? (O)
7. How does the type of material used effect battery characteristics? (O)
8. What steps can you use to optimize a Li-Ion battery? (O)
9. What kind of material properties are needed for a space elevator? (O)
10. How has the Trade-War affected the cost of materials/production? (O)
11. How pollutant are Renewable Energy materials to produce? (O)
12. Why do you space elevator when you space sling shot? (O)
13. How large of an inner radial distance (in AU) would a Dyson sphere need to be? (O)