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(Work in Progress) Implementing the QFT to Incite Curiosity and Connections in an Introductory Electrical Circuits Course for Non-EE Majors

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Abstract

It is often difficult for students to find interest or value in a first course on electric circuits. Students outside the field of electrical engineering may also experience greater difficulty. This course, primarily for aerospace and mechanical engineering majors, focuses on exposing students to basic circuit methods and terminology to prepare them for future courses and career in industry. The current dilemma professors experience while teaching these courses is providing relevant coursework while also improving class engagement. We propose using the Question Formulation Technique (QFT) coupled with simple research projects in our circuits course to incite curiosity and develop a questioning mindset. QFT developed by the Right Question Institute was introduced into the curriculum in the form of a semester long project. QFT engages students to develop their own personalized questions for research as opposed to classes that rely on the instructor simply assigning questions or topics for research. QTF focuses on the students developing an essential – yet often overlooked – lifelong learning skill of asking and creating good questions**.** The goals of this proposal are to generate curiosity and elicit connections for students on subjects they may have less exposure in and further develop students' soft skills. The project consisted of five prompts periodically spread out over the course in the form of an in-class activity. The students formed groups of 3-5 and generated questions that would then turn into an out-of-class assignment focusing on diving deeper into one of the questions created. The shorter assignments required students to do small amounts of outside research and write a paragraph about their chosen question. The students would then choose one of these paragraphs to turn into a larger essay for their final project assignment. For our initial assessment of the efficacy of our proposal, we are conducting a survey of students' experiences and responses to the QFT prompts. Initial findings show that the project helped broaden the students' knowledge of topics that are not particularly covered in depth, and they were able to discover connections between circuits and their other coursework.

Background

The aim of our research is to utilize the question formulation technique (QFT) [1] to create curiosity, connections, and cultivate soft skills in students. The basic elements of the QFT are shown in Figure 1. We are attempting to create not just a curiosity around the subject material, but also to help students to find connections between circuits and their other courses. Helping students uncover these connections should be a goal of any educator. However, if we can teach students the skills they need to discover their often-lost sense of curiosity, then they will control their own learning. Development of lifelong skills will serve the student long after their courses have been completed.

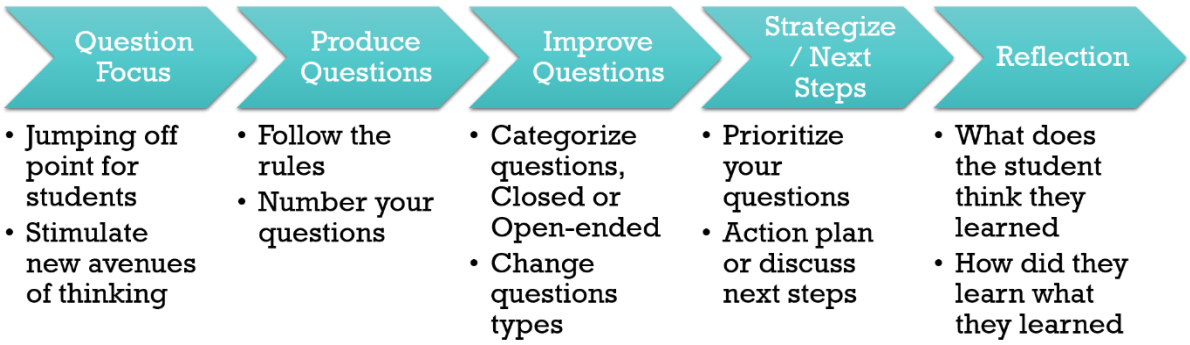

Figure 1: The basic elements of the Question Formulation Technique (QFT)

The students taking this basic circuits course are comprised of primarily aerospace and mechanical engineering majors. The question the authors have often heard repeatedly pertains to "Why should I take this course? I will never build a circuit in my life." The question of value to the student is hard to convey. Its conveyance is attempted in the course goals "One of the most useful skills an aerospace engineer must acquire to be successful is the ability to communicate with other team members in project environments." "It *(this course)* introduces a vocabulary and basic understanding of electrical design principles that are the central features of the electrical components of the aerospace system...". However, simply claiming to students that they will need to be good communicators with other engineers, has fallen short thus far.

For introductory courses in circuits, there are many techniques that have been utilized to try to make the course more engaging for students. [2]-[6] all help students integrate the theory with the practice by developing a method where students learn the material and then perform exercises related to the material. These methods attempt to create a way for the material to be more inviting. Either by doing active learning exercises, [2], [4], [7] or by directly linking the laboratory portion to the classroom [3], [5]. These techniques require a complete shift in some fundamental aspect of the course. Either flipping the classroom experience with videos or a MOOC, having the course and lab happen simultaneously, or completely changing the curriculum to accommodate project-based learning. These changes allow students to engage with the material, but not necessarily cause students to take ownership of the learning. This idea of "ownership" is not new, as the contemporary name most often associated with it is metacognition. Metacognition has many definitions, but we are most interested in the idea of self-regulation or self-learning. Helping students to direct their own progress by asking questions they are interested in pursuing. QFT yeilds higher rates of reflection on material by focusing on Inquiry-Based pedagogy[10].

This work was directly influenced by [8] in which their paper investigates some advantages of QTF. In their paper, they state "One of the key goals as an educator is to stimulate the curiosity of students in order to instill a desire to further explore and learn the subject matter outside of the classroom.". Their work was supported in part by the KEEN (Kern Entrepreneurial Engineering Network) program whose objective is to create students who have an entrepreneurial mindset. The mindset is "a collection of mental habits that empower you to question, adapt, and make positive change" [9]. The authors utilize the QFT to stimulate curiosity and hone students' ability to form questions in a circuits course. They found that students within the class room had greatly

benefited from QTF. Their initial results based on informal student feedback and anecdotal insights provided the basis from which we developed and expanded upon with our own research.

Proposed Plan

Finding relevancy and a purpose behind anything is the first step to success. Mechanical and Aerospace engineering students are required to take an introduction to circuits class as a part of their major. With the implementation of the question formulation technique, we strive to enhance their educational careers. By developing an environment that encourages students to ask their own questions, we aim to have students more involved and take charge of their learning. We also would like students to see the importance of understanding and not just reiterating. This process of understanding can only come when students take ownership in the learning process. The question formulation technique was implemented into the class through biweekly in-class prompts followed by a short research homework assignment. The prompts included dissenting statements that elicit students to question what would enable these statements. The first topic prompt, also known as the question focus, from [8] was" Ohm's Law is a Lie." This directly followed the lecture on Ohm's law as it applies to DC circuits. This appears to be a direct contradiction as to what was taught recently and incited the students to derive questions around the statement. Each question focus we used was designed to elicit a curiosity response from the students. It is not enough to just create a sensational statement, but rather the statement must create simultaneously a cognitive dissonance and a safe space to explore and ask questions. The goal is to produce eagerness, attentiveness, and a desire to discover.

QFT sets guidelines to help students formulate questions that are productive in the learning environment. For example, the questions should not be closed ended, i.e. be answered with yes or no answers. This induces progressive flow in the learning process. After shown the prompt, the students are given limited time in which they develop any question that pops into their head. This is typically done in a collaborative environment enabling the students to communicate ideas with one another. When the time is up, the students rank each question by interest, relevance, or effectiveness for investigating the prompt. They also are given time to convert closed ended questions to form open ended questions. Students are then asked to share one or more of their top three questions. Structuring the activity in this way increases focus and engagement on the topic.

Once students have finalized their three questions, each student picks one to further develop upon. Students will take their question topic and produce a paragraph that delves deeper via research. This out of class assignment is not entirely about the product that the student turns in, but more about the process the student takes to complete it. Answering a question that the student themself generated helps provoke curiosity in a way that answering the instructors' questions does not. This investigation mindset leads students to read articles, books, etc. and discover more about topics because there is a question in the back of their mind they are trying to answer. These actions help create a more well-rounded understanding of the topics discussed in the short time the instructor has in class.

The assignment was created with five basic criteria in mind: research and citation, terminology, curiosity/exploration, expanded knowledge, and, of course, following directions. The assignment requires proper citation of a resource where the information was obtained. The terminology must

be relevant to the course without being excessively technical. The chosen topic should be written about in a way that indicates interest in the subject matter. The essay should demonstrate that new knowledge was obtained. And the student should follow the guidelines for document formatting and length. So, while the QFT is used in class to help students think about things in a new way, the assignment was intended to help students to develop some of their other skills. Specifically, their ability to communicate in writing and acquire knew knowledge. These skills directly align with ABET student outcomes 3 and 7.

Lessons Learned and Future Work

This technique and project were implemented for the first time in the fall semester of 2022. One class of 35 students was the first cohort to go through the assignments described above. Two surveys were conducted over the semester. One given halfway through the semester and one at the end of the semester. The first survey was given to gauge the level of interest and how students perceived the project assignment's value, or lack thereof. The second survey was utilized to receive feedback from the students on what went well and what could be improved.

Significant feedback was received halfway through the semester. A student said in response to a general question about what could be done differently, that we should give some more guidance to the overall theme or purpose of the project. In the next class, we took some class time to discuss more about the project and its purpose. Many students expressed a similar sentiment after we had this in class discussion.

The second survey (given in the Appendix) asked students to rate on a five-point Likert scale to what level would they agree to various statements in order to gauge the students' interest and perceived value; as well as some open-ended questions. The numerical results of which are shown in Figure 2.

Figure 2: Results from the Likert questions on the student survey

When asked about the statement “The in-class question exercise is something that I look forward to.” Just over half of the students said they would agree or strongly agree with the statement. While almost 25% said they either disagree or strongly disagree. When asked about the statement “The project has helped me to discover some limitation or misconception present in my knowledge of the relevant topics discussed.”, over 80% said they agree or strongly agree with the statement. When asked about the statement “The project has helped me to draw connections to past and/or current coursework.”, just over 75% said they would agree or strongly agree. From these initial findings, it appears that the students thought the in-class portion of the assignment is something that could be improved upon. As mentioned previously, discussions about the purpose of the assignments and streamlining the in-class QFT experience would help student participation. It was also observed that even though students may not have looked forward to the class exercises, they did still discover new things through their research and made connections that they would not have noticed otherwise.

A difficult learning experience we encountered through the course of the semester was that not all question prompts work equally well in helping students develop their own questions. One example was a picture prompt that was based on a meme with a text that said “EE’s when the learn Ohm’s Law and Kirchoff’s Laws.” The prompt produced questions immediately, but the questions were mostly; what? and huh? Clearly not the responses we were aiming for. Whereas when we used an animated picture later in the semester, it conveyed clearly what would have been difficult with words. The prompt was “These are modeled the same way” with a picture of an RLC circuit and a bouncing basketball. Of the questions produced, one was “Can we model the basketball movement as a second order ODE?” This type of question was what we hoped might come from such a prompt. Allowing students to discover that the differential equations they learned in a previous class can be used to model very different systems in similar ways. Another student question was “What causes things to dampen?” Their answer drew directly from a project they had in their Dynamics class in which they modeled a ball being acted upon by outside forces. They were then able to connect the results of that project with the RLC circuits we were discussing in our circuits class.

Based on the feedback we received thus far, the next time this technique is implemented, we will open with a brief discussion about the purpose of the project and the assignments. This was a significant oversight that could have changed the outcome of many students learning. I think this simple step would set students up for greater success. Additionally, a topic that came up frequently in the feedback was the amount of class time devoted to the question making activity. After the first initial introduction, the students felt too much class time was devoted to just question creation and would prefer to do more on their own outside of class. We believe that since it was our first time implementing this technique that we also had some learning to do. Towards the end of the semester, we were only allotting ten minutes total time to the question formulation and class discussion. It is possible that the class time could be even less if the students are given more appropriate prompts. The creation of the prompt would need to be further refined in order to get the students into the useful question creation zone more quickly.

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Appendix:

Table 1: Project Survey Questions

Likert Scale Questions	The project helped me create a more well-rounded understanding of the course content?
	The project helped me discover limitations of my current relevant knowledge.
	The in-class QFT exercise was something that I looked forward to.
Open-ended Questions	What portion of the project's process do you think helped broaden your knowledge the most?
	What aspects of the project would you like to see changed and how?
	Which prompt was your favorite and why?
	What is a prompt you would have liked to see? Did you think of a good one we should have done or you would like to share?