Stimulating Curiosity and the Ability to Formulate Technical Questions in an Electric Circuits Course Using the Question Formulation Technique (QFT)

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***Abstract*—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. Another important goal, often underemphasized, is to enhance the student's ability to formulate questions relevant to the subject matter. In this paper, we describe a technique, called the Question Formulation Technique (QFT), which is well established in the K-12 environment, and elaborate on several ways in which QFT may be utilized to stimulate curiosity and hone question formulation ability in a core undergraduate engineering course, Electric Circuits. While many of the details of the QFT implementations are specific to the Electric Circuits course, the essential elements may easily be extrapolated to any core engineering course.**

Keywords—curiosity; self-directed learning; curiosity based learning; inquiry based learning; Question Formulation Technique (QFT); Electric circuits; entrepreneurial mindset.

I. Introduction

In a general sense, stimulating the curiosity of students is one of the most important goals of any educator. If successful, the student will be motivated to continue to learn and explore the course material outside the classroom and find connections with other information or applications relevant to their careers or everyday life. Instilling curiosity motivates students to become life-long learners. However, curiosity alone is not enough for effective learning.

Part of the learning process involves either assimilation of new information into the student's cognitive model of the world (both physical and metaphysical), or an adjustment of the student's cognitive model to accommodate the new information [1]. In either case, the student must cognitively interact with the information in order to learn it. As the new piece of information or subject matter challenges the student's cognitive model of the world, questions naturally arise in the mind of the student in order to probe the subject matter. Some of these questions are answered during the cognitive interaction with the subject matter, while others may require yet more information. Hence, questioning is part of the core of the learning process. Indeed, question formulation is a fundamental tool in the research process and scientific method that continues to lead to the discovery of new knowledge and paradigms.

Since question formulation is central to how we learn, it is critical for educators to utilize techniques that enhance the student's ability to formulate germane questions. It is important for a student to be aware of what they do not know and be able to articulate it in the form of a question. Curiosity combined with the skill of question formulation not only motivates, but empowers students to become life-long learners.

For more than half a century, psychologists have wrestled with understanding the nature of curiosity [2, 3, 4]. In [2], curiosity is associated with a spectrum of exploratory behaviors between diversive and specific. Diversive curiosity involves exploring unfamiliar topics or experiences, and is often associated with the senses, whereas specific, or epistemic, curiosity is focused and associated with a thirst for deeper knowledge within a topic. In [3], a desirable Zone of Curiosity is described, which is identified by optimal levels of excitement, interest, and desire for exploration. If an individual has low levels of excitement, interest, and desire to explore a topic, then motivation and efficiency will be lacking. On the other hand, if the levels of excitement, interest, and desire to explore are too intense, the individual may leave the Zone of Curiosity and enter the Zone of Anxiety. In [4], the individual variations in the capacity to experience curiosity (trait) and the levels of curiosity demonstrated in a specific situation (state) are explored using a trait-state inventory, which is shown to have acceptable levels of reliability and validity to justify its use as a research instrument.

From an educational perspective, [5] identifies ten instructional strategies to foster curiosity in students. The ten strategies are:

1. Use curiosity as a hook by posing a thought provoking question or surprising statement.
2. Point out a conceptual conflict, which elicits further exploration.
3. Create an environment that encourages questions.

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4. Provide ample time for exploration.
5. Allow student choices while exploring within a subject area.
6. Incorporate curiosity arousing elements, such as incongruity, contradictions, novelty, surprise, complexity, and uncertainty.
7. Provide the right amount of curiosity stimulation to bring students to the Zone of Curiosity, but not too much to drive them to the Zone of Anxiety.
8. Encourage exploration.
9. Allow the exploration and discovery to be intrinsic rewards; avoid extrinsic rewards.
10. Exemplify curiosity; i.e., ask questions, engage in specific exploration to resolve questions, and demonstrate enthusiasm.

In this paper, we argue that the Question Formulation Technique (QFT), originally developed for the K-12 environment by the Right Question Institute [6, 7], is a tool that can incorporate many, if not all, of the ten strategies identified in [5] to foster student curiosity. Moreover, the QFT helps students to develop the ability to formulate relevant technical questions in core engineering courses. We describe several ways the QFT may be utilized in a core engineering course, with specific details describing how the authors have implemented it in Electric Circuit courses.

The Electric Circuits course is a fundamental course within the Electrical and Computer Engineering curricula and is often a required course in other engineering disciplines (e.g., Mechanical, Biomedical, Chemical, or Civil Engineering). The topics of the course are often viewed by students as unfamiliar or abstract in nature. This leads to the underlying questions of this paper: How do we (as Electric Circuits instructors) stimulate the curiosity of our students to learn the fundamentals of electric circuit analysis, while also making the material more accessible to them? Furthermore, is it possible to train students to ask the thought provoking technical questions we would normally ask of them, in order for them to take ownership of course material?

Part of taking ownership of course material involves choosing the questions they wish to investigate, and generally becoming self-directed learners. The QFT enables students to generate many questions, which makes the process of choosing research questions easier for the student. The QFT is student-centered and semi-guided, which we claim make it a tool of Curiosity-Based Learning (CBL). CBL is a pedagogical framework, similar to Inquiry-Based Learning, that aims to stimulate student self-reliance and self-directed learning [8].

QFT applies three modes of thinking to engage students to formulate their own questions. First, divergent thinking is applied along with four cardinal rules to a question formulation exercise, centered on a pithy and germane question focus, called the QFocus, created by the instructor. Second, convergent thinking is applied to improve the clarity and direction of the generated questions, and to prioritize the more relevant questions. The instructor should devise an underlying purpose for the generated questions to be applied at this point. This is the step that allows for a variation of application of the QFT. Finally, an optional metacognition step is applied to reflect on the QFT process in order to improve student awareness of the importance of question formulation.

If used correctly, the QFT can be a powerful tool to stimulate student curiosity for research or design projects, or simply to help motivate one of the topics of the course. One of the keys to the success of the QFT is the nature and precise wording (or associated images) of the QFocus [6]. It is important for the QFocus to be declarative, imperative, or exclamatory in nature, rather than interrogative (i.e., a question). The QFocus is more effective if it is familiar and provocative, since a provocative QFocus will tend to elicit more questions than one that is either obvious or completely unfamiliar to the student. Another contribution of this paper is a list of QFocus statements for many of the topics typically covered in an Electric Circuits course.

The paper is organized as follows. Section II describes the QFT framework in detail. Section III details the applications of the QFT the authors have explored when teaching Electric Circuits. Finally, Section IV provides some reflections and conclusions on the implementation of QFT in Electric Circuits and other core engineering classes.

II. QFT Framework

Developed by the Right Question Institute [7], the Question Formulation Technique (QFT) is a step-by-step process that helps students learn how to produce their own questions, improve them, and strategize on how to use them. A fundamental assumption of the QFT is that students learn and retain knowledge better and take ownership of the learning process when, fueled by curiosity, they ask their own questions, and use them to drive their learning.

The QFT has been used as a popular pedagogical technique at the K-12 level [6]. At the higher education level, the QFT technique has been successfully used in improving student competencies in a Mathematical Modeling course [9]. It has also been used to improve student's ability to formulate carefully considered, evidence-based conclusions by locating and critically evaluating relevant information [10].

The QFT process starts with a Question Focus (i.e., QFocus). The QFocus can be a statement, an image, a quote, an object or anything else as long as it has a clear focus, stimulates student thinking on the desired topic and provokes students to ask questions – lots of them. The QFocus becomes the theme on which the students explore and begin asking questions. The more provocative or outrageous the object, image or statement the more questions it will generate. A well-developed QFocus may take several iterations, but in the end it should incorporate many of the ten strategies listed in Section I from [5] (especially strategies 1, 2, and 6). For our work, we have designed a number of QFocus statements specific to electric circuits, detailed in Section III.

Using guidelines from the Right Question Institute [7], and Dan Rothstein and Luz Santana's book [6], we provide students the following four rules (prescribed in [6]) for generating their questions and ask them to spend between 5 to 20 minutes "question storming".

1. Ask as many questions as you can.
2. Do not stop to discuss, judge, or answer any of the questions.
3. Write down every question exactly as stated.
4. Change all statements into questions.

Since students are typically used to "brainstorming" ideas, these guidelines are critical to the success of the exercise. We find that brainstorming sessions are typically dominated by a few members of the group and that initial ideas tend to set the tone for the remaining ideas that emerge from other members of the team. In "question storming" sessions, it is critical to force students to not discuss or pass judgement and to require that the questions be transcribed exactly as stated in order to create a safe, inclusive, and judgement-free space for all students (strategy 3). At this point, the goal for the students is to just ask questions – free from the burden of the "good question" or dominant personality (strategies 4, 5, 7, 8, and 9).

Before initiating the QFT brainstorming session, it is beneficial to review the overall QFT framework with the students, and it is critical to go over the four cardinal rules described above along with the reasoning behind why they are used. It is helpful to implement a group reflection activity, during which the student groups discuss the four cardinal rules, identify the challenges that make it difficult to adhere to the rules, and focus on the benefits of using the rules. We recommend creating a worksheet similar to the examples outlined in [6]. This exercise only needs to be done the first time the students are introduced to the QFT framework, and requires about 15 minutes of class time. Subsequent uses of the QFT framework only require a quick refresher of the four cardinal rules along with the steps of the QFT framework (requiring no more than 3 to 5 minutes).

Once the questions are generated, we ask the groups to spend at least 10 minutes to go through the questions and refine them as necessary. While refining, we ask students to identify questions that could be answered easily with a few words or a simple "Yes/No" response. These closed-ended questions might be of great value in certain situations, but are not as useful for our desired next steps in using the questions. Thus, we require students to rephrase closed questions to make them more open-ended and, therefore, useful for exploration.

After refining the questions, we ask students to review the entire list of questions, work together to prioritize the questions, and select the top three questions to use in the next steps (strategies 5, 8, and 9). For our class, we offer students a few (out of many) possible options for prioritizing questions:

- Choose the 3 most important questions.
- Choose the 3 questions that interest you the most.
- Choose the 3 questions that will help you best design your solution to the assigned project.
- Choose the 3 questions that move you toward your purpose.

We allow student groups to pick any three questions as long as they explain why they chose the specific questions. Overall, the entire process proceeds with minimal (to no) interaction between the students and the instructor. This lack of instructor involvement is essential as it eliminates potential bias or topical authority. Moreover, the instructor's intervention may stifle the question formulation process, if students become too focused on obtaining the "correct" question (strategies 7, 8, and 9).

III. Applications of QFT in Electric Circuits

The QFT framework outlined in Section II is described in detail in [6], with concrete reasoning provided to justify the specific details of the QFT construction. The aspects of the QFT that make it flexible to fit a given topic and underlying purpose are the QFocus and the follow-up exercise or project, which makes use of the questions generated in the QFT process. In this section, we describe the specific QFocus statements we have generated for electric circuit topics and describe some of the ways students have used the generated questions. Specifically, we describe a set of research projects and topic motivation exercises that make use of the QFT.

A. Research Projects

At the University of St. Thomas, the QFT was used to motivate student curiosity in the form of course research projects. A total of four QFT research projects were assigned. The course had a total of five accumulative topical exams (with no final exam), four QFT research projects, a set of labs, and daily learning exercises (not "homework") designed to emphasize and strengthen key concepts. Each QFT research project had the same weight as an exam in the calculation of final student grades in order to highlight the importance and seriousness of the activity.

Students were required to form groups containing four to six students. For the initial project, students were allowed to self-select. On the second project, the groups were instructor-selected. On the final two projects, students were allowed to self-select, but could not duplicate their original group. The scheme for selecting groups had no major impact (good or bad) on the quality of the research projects, as the rules for using the QFT adequately support the individual student and enable the group to flourish, regardless of the group selection.

Each research project began with a QFT question forming session guided by a QFocus. The beginning of each QFT question forming session was held in class, including the question generation process, but the remaining portions of the QFT, such as question prioritization and research, were required to be done outside of class by the students. The top three questions selected were used as research questions.

Students were given between one and two weeks to research the answers to the questions. Our hope was that students would do a literature search, learn how to do research and seek their own solutions to queries that arise during the process. Hopefully, these skills acquired during the QFT-based research projects will help the students seek and find answers to questions that arise during the rest of their Electrical Engineering education and beyond.

The main deliverable for the project was a paper that summarized the research questions and answered those questions with documented references. In addition, students were asked to reflect on the questions they raised, the answers they found and the overall QFT-based research process. During the reflection, students engaged in metacognition. In [11], the authors attribute metacognitive practices to increasing the degree to which students transfer their knowledge to new settings and events and how students draw connections from their other vast experiences.

The QFocus statements for the four research projects were

1. Ohm's Law is a lie.
2. y=mx+b is not linear'ity.
3. PHASORS–The EEs weapon of mass production (associated imagery included the starship Enterprise from Star Trek, pictures of grids, microgrids, circuits, a sine wave, a differential equation, and military defense technology).
4. Op Amp Oscillators–Amazing. (associated imagery included images of feedback block diagrams, classical transistor radios, and imagery from chaos theory)

The topics covered in the research projects by each QFocus, respectively, are: basic circuit laws, linearity and superposition, sinusoidal steady-state AC circuit response, and operational amplifiers.

Probably the most provocative of the four Q-Focus statements is the first. This project was assigned during the first week of the semester. The students in the course had just concluded their Physics-II course the prior semester with general understanding of Electricity and Ohm's Law. The goal of this project is for students to dive deeply into Ohm's law and understand it as an approximation rather than a law or theorem with a proof. Since the Electric Circuits course primarily deals with circuit analysis of linear elements, we want the students to learn based on their own research that there are elements that will be explored in subsequent courses for which a simple linear relation between voltage and current does not apply. To convey a sense of how a provocative QFocus can elicit interesting and deep questions from students, consider the following sample of generated student questions:

Who was Ohm? What is Ohm's law? What constitutes a law? Does Ohm's law have a reliable proof? Can we trust the outside source telling us Ohm's law is false? Why is Ohm's law commonly accepted, if it is false? What gives this outside source authority to tell us Ohm's law is wrong? What other theories and laws are incorrect? Why does Ohm's law work experimentally? What constitutes a lie? What if Ohm's law is true? Why would someone tell us that Ohm's law is a lie? Is Ohm's law an extension of the Work-Energy theorem? Why are we the first to know about this huge lie? Why does this project seem similar to that of a philosophy course? How accurate is the Ohm's law approximation? Are there other "approximations" we trust and use like "laws"? How can we approximate I, V and R in places where Ohm's law is inaccurate? How should we trust any of the laws and theorems in physics and engineering? How should we go about discovering the truthfulness of electricity? Can we understand electricity at all?

Another provocative statement is the second QFocus listed above. The goal of this project is to use the familiar equation of a line to stimulate thought and questions about the concept of linearity and the principle of superposition. This project produced the most interesting research and reflections. Most students commented that they never imagined how deep they had to go to obtain the answers to their questions because they had always considered y=mx+b to be linear (inducing conceptual conflict; i.e., strategy 2). Below is a sample of the questions generated by the students:

What is the definition of linearity as it pertains to mathematics, engineering etc.? How are uniqueness and linearity related (or not)? What are the assumptions made proving something is linear? What are the conditions for a linear circuit? How does linearity help us in our analysis of electrical circuits? How do real components vary from the linear models we use in analysis? If y=mx+b isn't linearity, in what form should an equation be to be considered linear? If y=mx+b is nonlinear, how can we make a linear approximation? How can the assumption that y=mx+b is linear affect our models of linear circuits? Why are we taught at a young age that y = mx + b is linear? What does a linear line look like in Homogeneous Coordinates? Why does linearity have a slightly different meaning between fields of study including mathematics? How do linear approximations change the results of circuit systems? Are there different scenarios where linear approximations can be made and when they cannot be made? What happens to a nonlinear and non-unique component in a circuit system? Does it not work? Is it not efficient?

Student curiosity was amplified by the QFT process and motivated students to dig deeper into the concept of linearity and its relation to circuits more than we have ever experienced with first and second year students. One group even went further, beyond our expectations, and read a journal article about chaos theory and jerk circuits [12]. This student group noted, "*One direction that our questions led us was to more questions. We found many other interesting things somewhat related to linearity. For example, some of us were led to chaos theory and the non-linearity of jerk circuits.*"

B. Topic Motivation

At Ohio Northern University, the QFT was used as a means to motivate two of the topics of the Electric Circuits course. Students generated questions on the topics, and in the first case, the instructor compiled the questions from all groups, answered them, and then used a portion of the subsequent class period (approximately 25 minutes) to summarize the questions and answers. In the second instance, the students were asked to research the topic of each of their questions and answer them briefly in under a page. In the second case, students were also asked to reflect on the QFT process as a whole. Since the instructor learned of the QFT framework from the other authors after the start of the semester (and hence nothing about QFT was mentioned in the syllabus), the follow-up exercise was offered as extra credit.

The two topics motivated by the QFT were transient response analysis of first-order circuits and root-mean-square (rms) values, also called effective values. The QFocus statements used for each topic, respectively, were:

1. For an RC circuit, forever is just five time constants away.

2. AC is *effectively* DC if effective values are used.

It is helpful if the QFocus has elements to it that are familiar and provocative. The first QFocus is a loose play on words from the familiar song “Tomorrow” in the play *Annie*: "Tomorrow, you're always a day away". It also creates a conceptual conflict (strategy 2) by equating the notion of forever with a finite length of time, which is of course normal for the analysis of continuous-time dynamic systems. The second QFocus uses repetition of the word “effective” in different contexts to elicit thought and questions.

For the use of QFT in topic motivation, the timing of when the QFocus is introduced is very important. If the QFocus is given without any introduction to the topic, students will know nothing about the topic of the QFocus. Conversely, if the QFocus is given too deep into the coverage of the topic, then students will focus too much on the information that has been already presented about the topic, which similarly stifles the question generation process. Further, the QFT will not be as useful for motivating the topic if too much information about the topic is covered beforehand. It is important to strike a balance so that students have been exposed to some basic information about the topic, preferably in an interactive hook (apply strategy 1). The key is to design the QFocus to target their knowledge gap, which elicits curiosity [13].

For the first QFocus statement considering transient response analysis, we had already covered analysis of DC resistive circuits as well as the basic functionality and current-voltage characteristic of capacitors. During the class in which the QFocus was introduced, we looked at the governing differential equation of a series RC circuit with the output taken as the voltage across the capacitor. We showed the form of the solution to this differential equation, and described it in terms of an analogy with fluid flow into and out of a storage tank. Finally, we introduced the notions of transient response, steady-state response, and time constant using the analogy. The analogy and aforementioned relation to RC circuits was covered on the same day in which the QFT was used, so students did not have the time to fully encode these concepts into memory. Hence, we feel the QFocus was well placed to target their knowledge gap, elicit curiosity, and enable them to generate many interesting questions. A sample of the questions generated is given below.

What does it mean by away? Away from what? What is forever in an RC circuit and how can it be measured? What is a time constant and how do you measure that? What is the time constant in relation to this circuit? What is the voltage across the capacitor when the circuit is closed, and what is the voltage when the circuit is open? What are the units for each element of the circuit? Is there anything that needs to be calculated from the given statement? Why five time constants to reach “forever”? What happens after five time constants? What if R or C are 0 or infinity? How can the 5 limit be applied to circuits other than RC? What values can we measure from an RC circuit and what do they tell us? How do RC circuits apply to mechanical engineering? What are the properties/characteristics/specifications of components of an RC circuit?

For the second QFocus considering rms values, we introduced the concept of effective values showing that the rms value of a periodic voltage waveform is the corresponding DC value of voltage that would equate the AC average power absorbed by a resistor given the periodic voltage waveform across the resistor to the DC power absorbed by the same resistor. We then showed the special case of the rms value of sinusoidal waveforms and used the concept of effective value to demonstrate the functionality of pulse width modulation (PWM) to control the speed of a DC motor. The QFocus was introduced after the discussion of PWM control of a DC motor. Some of the questions generated by students are given below.

If we can effectively use DC or AC, why don’t we always use DC? How can we find average DC or AC power? After getting the effective values, can we go back to AC values? What are effective values? What are the differences between AC and DC? Why is it valuable to have AC be DC? What things from DC apply to effective AC? What if effective values aren’t used? What application does this have to circuits? What makes AC effectively DC? How could this QFocus statement work the other way around? Is there more than one set of effective values, and if there are, what are they and how do you find them? Does this hold true at extreme values and if they don’t, then what do we do? Are there any drawbacks in using effective values with AC? How do you modulate pulse width? How do you change the duty cycle? Are we essentially modeling an AC circuit as a DC circuit?

IV. REFLECTIONS AND CONCLUSIONS

We decided to implement the QFT in our classes to use questioning as a way to promote student curiosity and to improve question formulation skills. We found it accomplished more than that. The QFT is an excellent way to promote not only student curiosity, but also creativity, critical thinking and teamwork. This technique allows young engineers to practice both divergent and convergent thinking, which are so critical to future success. The act of producing questions freely with a group of other students encourages divergent thinking in the students. Closely examining the questions that they have generated themselves, classifying those questions as closed or open-ended and analyzing which questions to prioritize promote convergent thinking.

A pleasant surprise we found when implementing the QFT was that when the quest to find answers to the initial questions lead to more questions, first and second year students go above and beyond what we traditionally expect of them. We were pleased to see our students search for and read journal articles. We were glad to hear about their trips to library research stacks and meetings with the research librarians. We were excited, for example, to see the students discover Maxwell’s equations in their investigations of Ohm’s Law and to see the students go through the different stages of enlightenment as they tackled the notion that y=mx+b is not a linear operation (if b is nonzero). We were thrilled to see them research linear and nonlinear devices and come up with their own answers to why real components vary from the linear models they had seen in their books. We were invigorated to see them draw a connection between their love for music to the operational amplifiers and to see their first "aha" moment about how they were already capable of building circuits to remove pesky noise that creeped into good music. For the topic motivations, we were pleased that many of the questions asked led to the next topics covered, which made students more engaged with the class material. We were particularly excited as students reflected on how they were going to remember this beyond the exams. One student wrote in his reflection, "*I retained the most by researching the questions my mind was most curious about because that is the information that my mind really wanted*".

We emphasize again that the nature of the QFocus is key to stimulating the curiosity of the student and enabling the question generation process. To stimulate thought, the QFocus should be pithy, provocative, and familiar to students. It should target the desired subject matter and ideally illuminate the knowledge gap of the student and drive the student to want to explore that knowledge gap. Several of the strategies listed in Section I from [5] should be considered when formulating the QFocus, especially strategies 1, 2, and 6. The exact form of the QFocus is the primary component of the QFT the instructor fully controls. The rest of the QFT process is constructed to be primarily student-driven, and should remain student-driven.

One example of a QFT exercise the first author has implemented that was not as successful focused on the topics of the final exam. The QFT exercise involved several QFocus statements, where each QFocus was simply a list of a few of the topics covered in the class. The aim of this QFT exercise was to generate questions for the final exam review. In principle, the QFT is a useful tool in review situations, as it guarantees students have questions to ask during the review. However, given the poorly devised QFocus statements, the question forming process was noticeably more labored than the prior two experiences. While the topics were familiar, the QFocus was not provocative, nor interesting, and it did not target the knowledge gap of the student. It included none of the elements of strategies 1, 2, or 6. Although far from ideal, this QFT exercise did generate many questions for the review. In summary, we recommend to give the QFT a try, even if the QFocus created the first time is not optimal. More tips, advice, and examples of QFocus statements may be found in [6].

Given that the QFT framework requires about 15 to 20 minutes of class time to introduce, only about 5 minutes to refresh, between 5 and 10 minutes to generate questions, and between 5 and 10 minutes to prioritize them, it is a tool that can be used for any core engineering course without taking too much class time. If the framework can be introduced in a first-year course, such as freshman orientation or introduction to engineering, then it will require even less time in the core engineering course. Based on our experiences, this time has been well worthwhile. Other examples of ways that the QFT may be used include: an introduction to a design project, generating questions for a guest speaker, or motivating a laboratory experiment.

One important topic notably absent from this paper is assessment of the QFT beyond informal student feedback and our own anecdotal experiences. We have made the case that QFT is grounded in Curiosity-Based Learning and can support the instructional strategies of [5], but we have not assessed the extent to which the QFT has improved the learning outcomes of the course. More rigorous assessment is left for future work.

We leave the reader with a final student quote reflecting on the QFT: "*Acquiring an understanding of the original question necessitated we question everything, take every aspect of the subject apart and formulate a more complete understanding. Filling the gaps in our understanding naturally led us to formulate new questions to answer. We repeated this process several times until we ultimately uncovered as much of the truth as we could. We kept asking questions.*"

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REFERENCES

[1] T. Healy. "Work in progress: curiosity in the education of the engineer", *Proceedings of the Frontiers in Education Conference* (*FIE*), pp. 6-7, 2005.

[2] D. E. Berlyne. "Conflict, arousal, and curiosity", McGraw-Hill, New York, NY, 1960.

[3] H. I. Day. "Curiosity and the interested explorer", *Performance Improvement*, Vol. 21, No. 4, pp. 19-22, 1982.

[4] F. D. Naylor, "A state-trait curiosity inventory", *Australian Psychologist,* Vol. 16, No. 2, pp. 172-183, 1981.

[5] M. P. Arnone. "Using instructional design strategies to foster curiosity. ERIC Digest," *ERIC Clearinghouse on Information and Technology*, Syracuse, NY, No. ED479842, 2003.

[6] D. Rothstein and L. Santana. "Make just one change: teach students to ask their own questions", Harvard Education Press, Cambridge, MA, 2015.

[7] The Right Question Institute, www.rightquestion.org.

[8] R. Jackson and A. E. Ward. "Curiosity based learning: impact study in 1st year electronics undergraduates." *International Conference on Information Technology Based Higher Education and Training (ITHET),* pp. 1-6, 2012.

[9] J. A. Pelesko. and M. Cirillo. "The question formulation technique: a tool for teaching mathematical modeling." Available online at http://modelwithmathematics.com/wpcontent/uploads/2016/04/QFT_Pelesko-Cirillo.pdf.

[10] V. M. Bhavsar, C. M. Dypiangco, and R. Moreau. "Fifty questions: encouraging students to ask questions and evaluate information." *Natural Sciences Education*, Vol. 45, No. 1, 2016.

[11] National Research Council. "How people learn: brain, mind, experience, and school: expanded edition." National Academies Press, Washington D.C., 2000.

[12] J. C. Sprott. "A new chaotic jerk circuit." *IEEE Transactions on Circuits and Systems II: Express Beliefs*, Vol. 58, No. 4, pp. 240-243, 2011.

[13] G. Loewenstein. "The psychology of curiosity: A review and reinterpretation." *Psychological Bulletin*, Vol. 116, No. 1, pp. 75-98, 1994.