K-12 STEM Education
Vol. 4 No. 1, Jan-Mar 2018, pp.305-311

The Challenges of Figure Overuse in STEM Education: Lessons Learned From the Recent History of Science Education

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Abstract

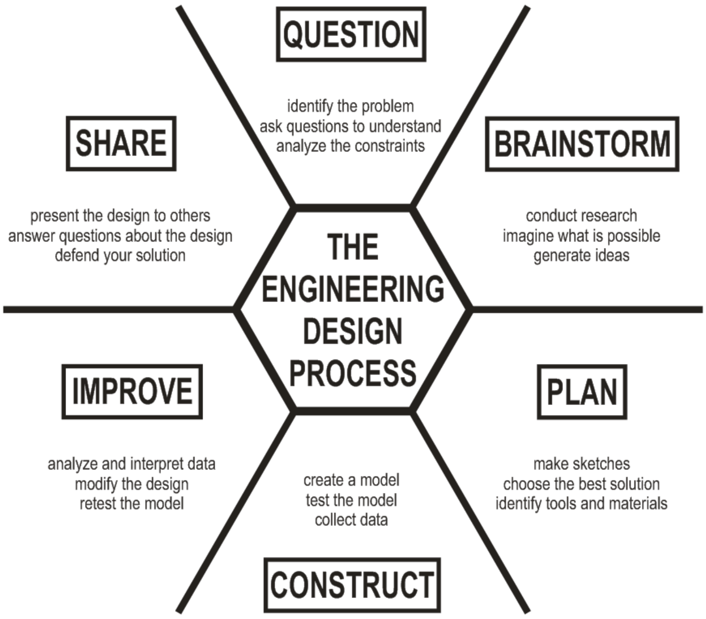
In technology and engineering education the design loop has become ubiquitous. For example, the authors challenge you to go into any technology and engineering classroom, and not find some form or fashion of the design loop, process, or method displayed prominently on the wall. Similarly, if you were to survey pre-service teacher candidates about their definition of "engineering", they would likely refer to the design loop, process, or method. The science education community faced a similar situation in the past regarding "the scientific method". In fact, the scientific method has even become pervasive within the public's view of doing science. Perhaps it is time to rethink how we present the design process to students.

Keywords: STEM Education, The Design Process, Technology and Engineering Education

Introduction

When faced with a challenging problem to solve, it would be nice in theory to have all of the time in the world to develop a series of prototypes as an optimal final design solution. The reality however is that time is often at a premium when it comes to design-based problem solving in the classroom. The possibility exists that we could be forced into designing immediate solutions to problems under a time constraint. Imagine being stranded on a desert island or other region in which no resources beyond those naturally provided are available. Human nature is that we will immediately begin developing solutions to meeting our most essential and basic needs; no process or graphic is needed, especially if the sky is darkening, you are cold, hungry, and tired…as a hurricane approaches on the horizon.

The issue that we raise in this paper is related to the above example. We are concerned that students (particularly those in K-12 classrooms) are introduced to an overly simplified version of the design process used in technology and engineering education classrooms at the expense of deep discussions of exceptions, complications, and nuances that are the hallmark of authentic engineering and ultimately the abilities needed for real-world problem solving. In practicality these discussions are sometimes challenging to hold in a classroom setting, and an understanding of foundational concepts related to engineering design would be needed prior to going more in-depth. We believe it is the task of those in higher education and in K-12 classrooms to set the tone for how we intend to teach our students so as to avoid potentially misleading them and ultimately foster authentic STEM learning.



This is an example of the design process from the perspective of technology and engineering education (Daugherty & Carter, 2017).

Figure 1. *Example of the design process.*

In our communities of practices, specifically in education, being thoughtful about accepted models utilized in teaching and learning does not often take place. Perhaps it is because people want things laid out in a specific and easy to understand format. We want posters on the wall that we never have to take down, a constant reminder that reinforces our teaching practices. Educators discuss best practices, yet particularly in technology and engineering education, we continually model an iterative design process, all while repeatedly telling our students that the design process is not an iterative, non-linear process. This can also be said in the science education community.

It is not enough to just have a poster on the wall. There must be explicit and meaningful conversation with students about the merits and limitations of a necessarily simulated model of the problem-solving process. Some might say that these types of conversations should only happen in a higher education setting, but these are the types of discussions that need to happen in K-12 classrooms and in pre-service teacher education.

The challenge of conceptual representations in STEM classrooms

Currently there is a shift in education to focus less on facts (rote knowledge and memorization) and more about the process of how knowledge is constructed. This is evident in the inclusion of both science and engineering practices in the Next Generation Science Standards (NGSS) (Lead States, 2013), which is a large component of STEM teacher education in the United States. There is a natural tendency to want to streamline teacher education for the sake of efficiency. We want to give in-service and pre-service teachers a tidy packet of knowledge that can be hung on a classroom wall for future student reference. The benefits of visual aids for students and teachers alike of appropriate heuristics does come with undeniable benefits, i.e., the ability to select pathways when conducting investigations or solving problems. However, the limitations and perhaps dangers are less obvious. These dangers may include:

- Classroom conversation and resulting creative decision making may be stifled as an unintended consequence of poster-shock;
- Design in engineering and investigation in science rarely comes to a definitive ending point; and
- The use of a pathway on a classroom wall (whether linear or cyclical) has the potential to encourage a rushing of the process. Obvious classroom constraints (time, number of students, resources, etc.), make this approach desirable at times, but are we replacing teacher expertise with whatever the current poster or graphic emphasizes?

How many times do we expect teachers to take down the old poster and tape up the new one? We know teachers are resistant to change (Chen, 2010) and we have all seen classrooms that are wallpapered with visual aids and resources from decades past. Teachers with the most on their walls could be perceived as those who are most active in their field. As a result, there is the potential for classrooms to have multiple posters displayed that were originally created for the same purpose. For example, in science education old posters representing the processes of scientific inquiry are likely to be found hanging side by side with the latest NGSS graphic emphasizing the practices of science. This may result in both students and teachers being confused about which model to follow and any possible contradictions within them. We lose a common language, certainly a language that can and should evolve.

Lessons from Science Education

Science education as a discipline has been evolving for at least the past one hundred years within the United States (DeBoer, 1991). Over that time trends have come and gone and then reappeared again. As a result, the language within the science education community has been changing and subsequently the ways in which we communicate and represent those ideas to pre-service teachers have evolved. One example of this is the myth of the scientific method. From the earliest days of science education, the hypothesis has been strongly emphasized as being part of what could easily be interpreted (even if this was not the intent) as a relatively strict and singular scientific method (Cohen & Nagel, 1934). However, it was not long before the limitations of a step-wise scientific method as applied in a science classroom were clearly articulated.

> Nothing is further from the procedure of the scientist than a rigorous tabular progression through the supposed "steps" of the scientific method, with perhaps the further requirement that the student not only memorize but follow this sequence in his attempt to understand natural phenomena (Harvard Committee, 1946, p. 158).

Apparently, the science education community did not receive this message. The myth of the scientific method as a step-wise singular cookbook style formula to be followed at all times in order to arrive a certain and unquestionable facts about the universe has been a key aspect of the Nature of Science (NOS) being emphasized in science education research for decades (McComas, Almazroa, & Clough, 1998). To this day, researchers are assessing teachers' and students' views of scientific inquiry in order to gauge their understandings of the myth of the scientific method (Lederman, Lederman, Bartos, Bartels, Meyer, & Schwartz, 2014). The reason that this is still emphasized and studied is that students and teachers alike continue to hold naïve views regarding the strictness of a singular and linear stepwise scientific method. Perhaps this is due to classic posters that we have all seen in countless science classrooms that proclaim as much. This myth of the 1930s then was and has been perpetuated all these years later. The science education community is still trying to tear down posters and get science teachers and students to think about methods and practices of science rather than the classic pattern of the scientific method. Parallel issues can also be found in technology and engineering education.

Design methodology in the technology and engineering classroom

In Cross' (1993) History of Design Methodology, the author pinpoints that design methodology as an academic discipline can be traced back to the 1962 Conference on Design Methods. Cross goes on to summarize the history of design methodologies developed throughout the 50s and 60s, their wane during the late 60s, re-emergence during the mid-70s due to Horst Rittels' work on the subject of design thinking, and then popularity during the 80s as both the scientific and engineering communities embraced the process, practices, and methods of design. During this evolution of design thinking, Simon (1969) published one of the earliest models of the design process consisting of the stages: problem definition, research, formulate ideas, select or choose the best idea, prototype or model, implement, and learn. Over the years this model has been modified and adapted countless times in both industry and education. The practice of design thinking was reflected in the then field of industrial arts education and transitioned into the redefining and name change to industrial technology and then technology education in the 80s and 90s as design thinking became a predominant area of emphasis in the profession. In 2010, the technology education community adopted the name of technology and engineering education (International Technology and Engineering Educators Association, 2010). The design loop, method, or process is now ubiquitous in the technology and engineering education classroom.

The current consensus pieces of the design loop include a range of steps from problem identification to communicating or sharing the results of the design with the ultimate goal of scaffolding the think practice that engineers or designers use when approaching a problem (See Figures 2 & 3). Typically engineering or design challenges are seen as non-linear problems with an authentic focus that reiterates that design is never-ending. With the recent release of the NGSS (2013) many educators have adopted the engineering practices within the science and engineering practices and define these steps of the process as: defining problems, developing and using models, planning and carrying out investigations, analyzing and interpreting data, using mathematics and computational thinking, designing solutions, engaging in argument from evidence, and obtaining, evaluating, and communicating information.

The challenge in the technology and engineering education community is to remain focused on the authenticity of design, lest the design loop become knowledge to be purely memorized rather than a thoughtful process used to develop solutions to real-world problems. Just as with scientific inquiry, there is value in forcing students through the process (loop) in the design. It is important to emphasize how this learning can be transferred into everyday problem-solving.

Conclusions and recommendations

In light of the constraints of public education--time, money, etc.--it is quite comfortable for the classroom teacher to follow a specific set of steps or directions to help scaffold a student's thinking process both in the science and technology and engineering classrooms. However, we are concerned that going through the motions of a linear or non-linear approach may stifle a teacher's passion or enthusiasm for learning that may then trickle down to students. The perceived value of streamlined simplicity of an easy to follow, neat and tidy, canned, formulaic recipe is enticing to teachers in an era of best practices. In the process of streamlining or simplifying teaching methods, the process of science and engineering practice may actually weaken students' abilities to engage in an authentic experience.

Things like scientific processes and engineering design practices are diverse and therefore in practicality challenging to teach. As teachers, we sometimes want to give students something to readily memorize or access. It is important that we provide students with opportunities to personalize and develop their own representations of these practices of science and engineering. For example, in an elementary STEM teacher education program, students are asked to conduct research on the various models of the engineering design process, and then construct a graphic representation that they might use in their future classroom. Below are two examples of the personalized graphics.

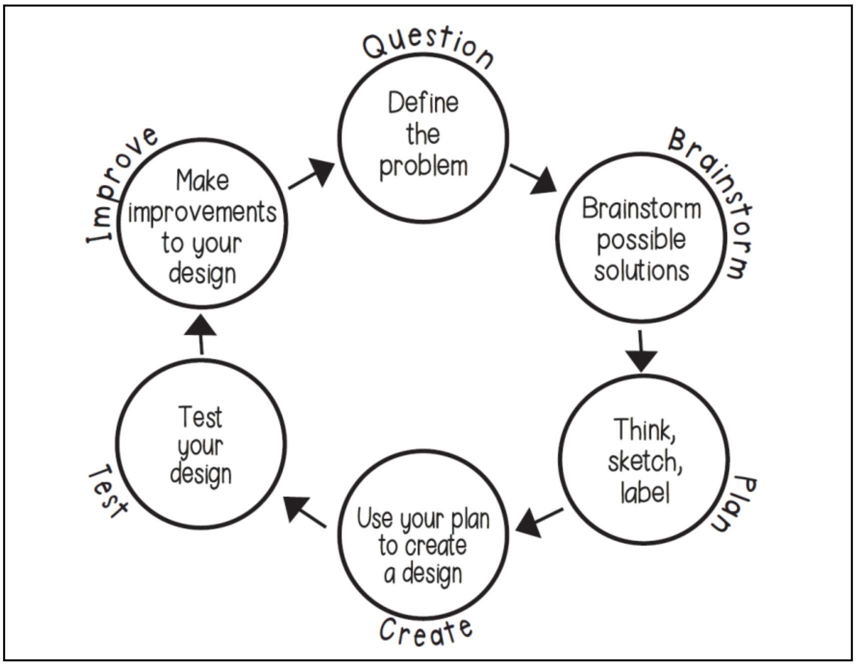


Figure 2. *Student 1's representation of the design process.*

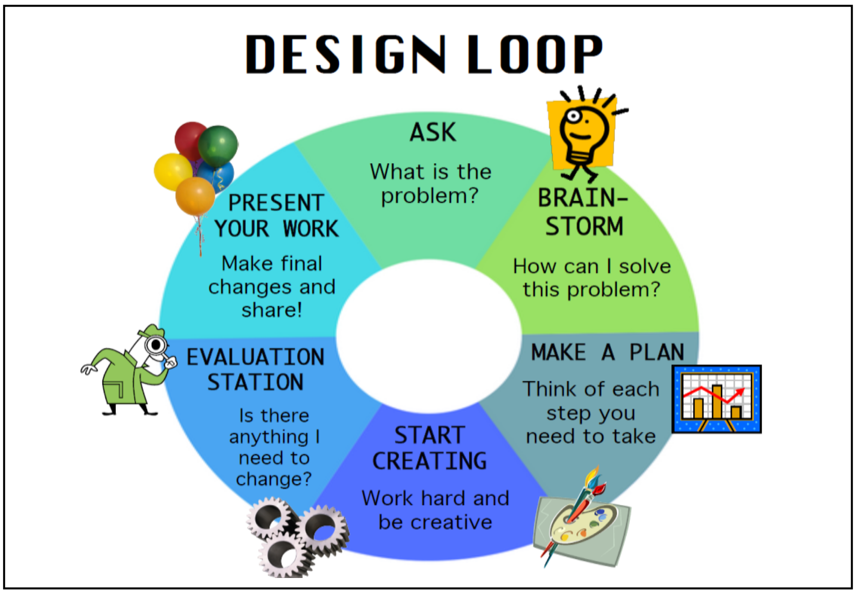


Figure 3. *Student 2's representation of the design process.*

In comparing Figures 2 and 3, both similarities and differences can be seen. For example, Figure 3 concludes with the presentation of work and sharing with others, while Figure 2 concludes with making improvements of the design. Additionally, Figure 3 emphasizes creativity with the act of constructing or building in a way that Figure 2 does not. In the classroom, we recommend that STEM teachers provide students with opportunities to internalize the process by creating their own designs and presenting them to their peers. By doing this, students would realize that the practices of engineering cannot be summed up in a convenient and universal poster to commit to memory, but rather the students would come to understand that the practices of engineering are diverse yet share important features.

If we as teachers are only striving to teach students to label a diagram, repeat back information, and complete a check-list on a science or engineering graphic, we may in fact hinder their ability to later assimilate learning. The ultimate goal is that students are able to apply science and engineering practices in their daily lives. We should be teaching for transfer, not necessarily for process.

Acknowledgements

The authors would like to acknowledge Morgan Kazanovicz and Chloe Nanos for giving us permission to use their figures.

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References

Chen, C. H. (2010). Why do teachers not practice what they believe regarding technology integration? *Journal of Educational Research, 102*(1), 65-75.

Cohen, M.R., & Nagel, E. (1934). *An introduction to logic and scientific method*. London: Routledge.

Cross, N. (1993), A history of design methodology. In M. J. De Vries, N. Cross, and D. P. Grant (Eds.), *Design methodology and relationship with science*. Dordrecht: Kluwer Academic Publishers.

Daugherty, M. K. & Carter, V., (2017). The nature of interdisciplinary STEM education. In de Vries, M. J. (Eds.), *Handbook of technology education (pp. 1-13).* Springer International.

DeBoer, G. E. (1991). *A history of ideas in science education: Implications for practice*. New York: Teachers College Press.

Harvard Committee. (1946). *General education in a free society: Report of the Harvard Committee*. Cambridge, MA: Harvard University Press.

International Technology and Engineering Educators Association (ITEEA). (2010). *ITEA officially becomes ITEEA*. News release, Reston, VA. Retrieved from www.iteea.org/AboutITEEA/NameChange.pdf

Lederman, J. S., Lederman, N. G., Bartos, S. A., Bartels, S. L., Meyer, A. A., & Schwartz, R. S. (2014). Meaningful assessment of learners' understandings about scientific inquiry—The views about scientific inquiry (VASI) questionnaire. *Journal of Research in Science Teaching*, *51*(1), 65-83.

McComas, W. F., Almazroa, H., & Clough, M. P. (1998). The nature of science in science education: An introduction. *Science & Education*, *7*(6), 511-532.

NGSS Lead States. (2013). *Next generation science standards: For states, by states*. Washington, DC: The National Academies Press. Retrieved from www.nextgenscience.org/next-generation-science-standards

Simon, H. (1969). *The sciences of the artificial*. Cambridge, MA: MIT Press.