

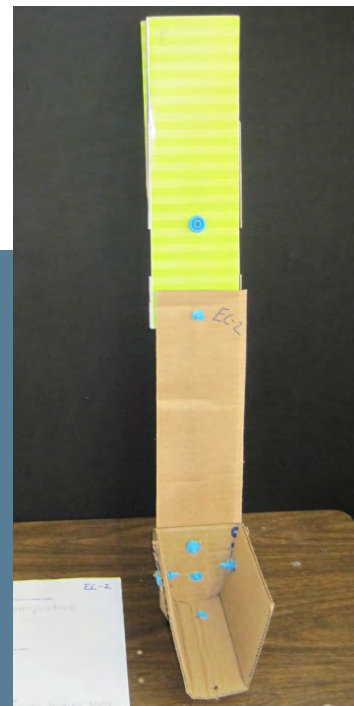
design fixation in STEM teacher education

by Leah R. Cheek, Vinson Carter, and
Michael K. Daugherty

Even with the best of intentions, educators focused on a pedagogy that encourages creative competence and innovation in their students may unknowingly hinder student creativity and lead them to developing increased levels of design fixation.

Introduction

As technology and engineering educators affirm, the engineering design process is the cornerstone of our profession and the way that we structure problem solving to guide students in developing innovative solutions to scenarios presented in design challenges. This primary role of engineering design is echoed in the new *Standards for Technological and Engineering Literacy (STEL)* document, where it is noted that “the processes of designing, making, and doing have long been hallmarks of the technology and engineering education laboratory-classroom and provide ample opportunities for students to consider and apply content knowledge, skills, and dispositions from many disciplines” (ITEEA, 2020, p. ix). *STEL* also emphasizes the importance of the design process in solving problems. The Standards note that “design in technology and engineering is by nature a creative process...innovative solutions use resources in unique and unexpected ways...” (ITEEA, 2020, p. 56). However, technology and



Variety of reach extender builds from scenario two.

engineering educators often lament the lack of student creativity in the solutions they propose to design challenges. These educators regularly seek strategies to help foster higher levels of creativity and innovation among student problem solvers.

Creativity is the ability to look beyond the typical for multiple ingenious solutions to a problem. According to Sawyer (2015) creativity plays an important role in how students take learning beyond the classroom. Furthermore, the Partnership for 21st Century Skills (2007) affirms “the best employers the world over will be looking for the most competent, most creative, and most innovative people on the face of the earth and will be willing to pay them top dollar for their services” (p. 7). Some mistakenly view creativity as something bestowed on the lucky few and something exemplified by the “aha” moment; however, good teachers can offer conditions that promote creativity through ill-structured engineering design challenges (Schut, Klapwijk, Gielen, van Doorn, & de Vries, 2020).

Unfortunately, even with the best of intentions, educators focused on a pedagogy that encourages creative competence and innovation in their students may unknowingly hinder student creativity and lead them to developing increased levels of design fixation. Design fixation is the often-unconscious reliance on finite solution ideas during the design process (Jansson & Smith, 1991). When students fixate on a solution, their creativity becomes stagnant, and they are unable to envision other ways to design a solution to a given problem. This fixation hinders the creative process necessary to solve elegant engineering design challenges in the classroom, but more importantly, defeats the creativity that students may need in their future educational or career endeavors. According to Kelley (2020), “design fixation is a real phenomenon, and students are very sensitive to impulses that might lead them toward design ideas” (p. 10).

Background

The challenges of design fixation also exist in the teacher education classroom where the fundamentals of the design process are instilled in teacher candidates. Torrance (1965) defined creativity as, “... the process of becoming sensitive to problems, deficiencies, gaps in knowledge, missing elements, dis-harmonies, and so on; identifying the difficulty; searching for solutions...” (p. 663). It is likely that the majority of teacher education students are digital natives raised with the idea that *Google* or *YouTube* is the keeper of all “right” answers. Kelley and Sung (2017) confirm that “students often go and conduct online searches for existing solutions or locate blogs about the topic” (p. 17). Teacher candidates frequently replicate these obvious or “cookie-cutter” designs presented on the internet and habitually expect teacher educators to provide images or models of potential solutions when design challenges or problem-solving activities are used in class. The replication of these obvious solutions may be more focused on quickly completing the challenge or assignment and may remove the students from making powerful connections or considering how the design may affect the end user.

Bonnardel and Pichot (2020) have also suggested that if designers take a more active role in gathering information about the end user, the designer may have greater empathy resulting in increased creative solutions for the intended user of a design. This affirms the previous research by Johnson et al. (2014) that successful design originates from the understanding and development of empathy for consumers. Edelen, Bush, Cook, and Cox (2019) also suggest that “students develop an immense compassion for the person(s), organism(s), or environment(s) for which they are solving the problem and begin to seek out the knowledge they need to solve the problem...” (p. 11). Design fixation may be mitigated through the elimination of samples or models as well as the intentional inclusion of empathy during a design challenge or problem-solving activity in the classroom.

To investigate the role of design fixation during engineering design challenges and problem-solving situations in the classroom or laboratory, the researchers isolated and focused on two primary questions related to potential creativity obstructions during engineering design challenges:

1. How do models or images of previous design solutions related to the engineering challenge cause design fixation?
2. How does the addition of empathy, such as adding an “empathetic character,” in a engineering design challenge increase creativity?

The following investigation occurred within two different sections of a pre-service teacher education class entitled, *Introduction to STEM Education*, in which both secondary and elementary teacher education candidates were enrolled.

Scenario One

At the beginning of the semester, students in two class sections were presented with the “Touchdown” design challenge, based on the NASA Jet Propulsion Laboratory classroom activity available at www.jpl.nasa.gov/edu/teach/activity/touchdown/. The students, using previous schema about gravity, motion, and forces were randomly assigned to engineering design teams using Kagan SelectorTools™ and challenged to build a shock-absorbing spacecraft capable of protecting two “astronauts” as they landed on the surface of the “moon.” After sufficient team ideation and allotted time to design a spacecraft, teams were asked to test the outcome by dropping the spacecraft design models from three distinct heights. The challenge was considered “successful” if the “astronauts,” represented by large marshmallows, remained within the spacecraft upon impact.

Student engineering design teams in both class sections were supplied with the same basic materials: cardstock, small paper cups, index cards, rubber bands, plastic drinking straws, scissors, tape, and mini marshmallows. The same instructor presented the challenge to both class sections with oral and written directions. Both classes were given identical instruction, materials, and limitations. The students in the control class section were provided with illustrations (models or pictures) of previously seemingly successful designs,

whereas students in the experimental class section were not provided with illustrations (models or pictures) in the design brief.

Scenario One Findings

The control group, provided illustrations (models or pictures), overwhelmingly imitated the modeled solutions in their own designs (See Fig. 1). Additionally, this control group rapidly began attempting to build solutions mimicking the illustrations, with little noted ideation or discussion among group members.



Figure 1. Control teams presented with illustrations (models or pictures) of seemingly successful spacecraft designs that not only mimicked the accordion-build of the model but were near duplicates of the other teams' designs.

The experimental class section did not receive illustrations (models or pictures) and appeared to develop much more creative and diverse solutions to the challenge (See Fig. 2). The engineering design teams in the experimental section expended a substantially greater amount of time with ideation before moving on to develop and create their solutions. These findings mirrored Chrysikou and Weisberg's research as stated, "although intended to suggest other possible solutions, those examples might, instead, have

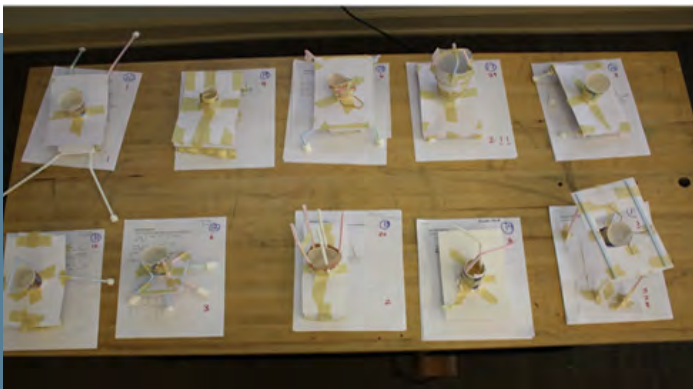


Figure 2. Experimental teams not presented with illustrations (models or pictures) of seemingly successful spacecraft spent more time ideating and built creative solutions that were less similar.

an inhibiting effect, restricting the problem solver to use the components of the example design ..." (Chrysikou and Weisberg, 2005, p. 1135). Teachers will often use examples such as images, illustrations, and models, believing it helps students understand the problem, but in fact this appears to limit the creative process.

Scenario Two

Following the completion of the Scenario One experiment, the researchers structured an engineering design challenge to investigate the relationship between empathy and creativity. Like the previous scenario, students in two different sections of the pre-service class *Introduction to STEM Education* were presented with the same challenge, but this time students were asked to build a reach extender. Teams were randomly assigned to student engineering design teams in both class sections using Kagan SelectorTools™ and received the same engineering design brief, guidelines, and limitations. The engineering design brief called upon the teams to develop a reach extender that would add at least twelve inches to a student's arm length and be capable of retrieving a pencil dropped on the floor. The supplies used in the challenge included only recycled cardboard and Makedo® tools/fasteners. Additionally, scissors and cardboard (Canary®) cutters were also supplied. The challenge was considered successful if the reach extender added twelve inches or more to a student's arm length and allowed them to retrieve a pencil from the floor.

The same instructor presented the challenge with oral and written directions in both class sections. No models were used. This time the treatment came in the form of the inclusion of an "empathetic character." The control class section received only the instructions before beginning ideation. The experimental class section was first introduced to an "empathetic character" who required the assistance of a reach extender. In this case, the engineering design teams were unaware they were speaking to an actor who visited the class. The wheelchair-bound empathetic character actor described how an accident had temporarily caused her to be unable to do some simple things for herself. She specifically described how picking up her own dropped pencil caused her much distress, as she had to repeatedly call on others for help. The instructor then proceeded to present the specifics of the engineering design challenge and asked the students to help create some ideas with the simple tools and materials provided. The students understood that they were designing a short-term solution, that might be further developed later. The empathetic character actor remained in the classroom during the challenge.

Scenario Two Findings

The control class section without the empathetic character quickly began ideation and the development of solutions in their engineering design teams. Many of the teams began sketching potential solutions, and considerable collaboration

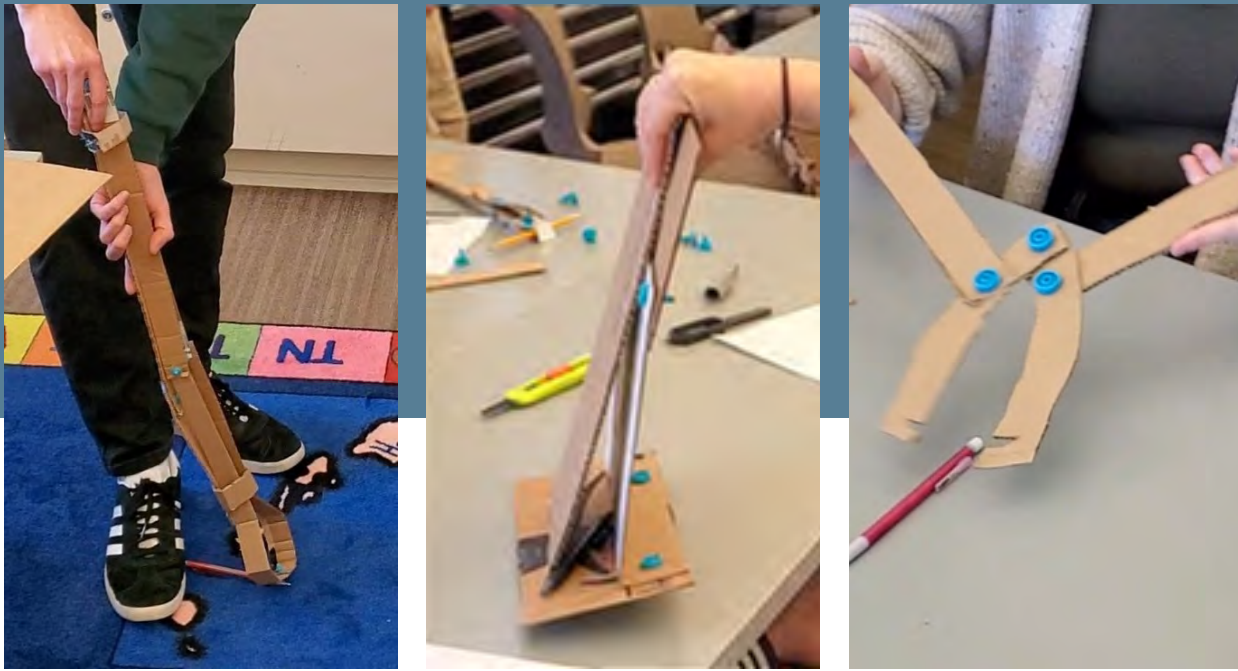


Figure 3. Control teams without the empathetic character created a variety of innovative builds.

and discussion occurred. The mood in the classroom was calm and relaxed and the students appeared motivated. Many of engineering design teams were successful in the challenge and the results showed a variety of creative solutions (See Fig. 3).

Surprisingly, the experimental class section teams, who met the empathetic character actor, behaved in a completely opposite and unexpected manner (See Fig. 4). The engineering design teams seemed apprehensive to get started, while considering the prospect of designing a solution for a real person. There was little discussion in the groups. One participant was overheard quietly saying to her design team, "I'm worried it won't work. She is a real person. The last couple of things we designed and created didn't really matter." The students in the experimental group seemed to be troubled or burdened with the seriousness of the challenge. Finally, one group asked the character actor if she planned to take the reach extender to school. Other groups began to ask the actor questions. With encouragement from the instructor due to the time constraint of the class meeting time, the engineering design teams began to build, but there was a great amount of "corporate espionage" in which the teams borrowed heavily from others. Finally, one group constructed a successful solution, and soon the other groups built almost identical solutions.

At the conclusion of the engineering design challenge, the teams in the experimental class were informed the empathetic character did not actually require a wheelchair and was in fact an actor. Many of the students expressed that the pressure to design and test a solution for a real person, who was present in class created a great deal of anxiety. One person exclaimed, "The stakes were too high!"



Figure 4. The empathetic character demonstrated the problem, and the resulting builds lacked creativity.

Discussion

In order to analyze and contemplate the results, the instructor/researchers returned to the original questions that sparked this inquiry:

1. How do models or images of previous design solutions related to the engineering challenge cause design fixation?
2. How does the addition of empathy, such as adding an “empathetic character,” in an engineering design challenge increase creativity?

As expected in Scenario One, the control group, provided with samples and illustrations at the introduction of the challenge, quickly mimicked the examples. This finding aligns with the research of Bartholomew and Ruesch (2018), in which they state, “... once a potential solution to a problem has settled into one’s mind, it can be difficult to break from the original idea and move in a different direction” (p. 27). Furthermore, Condoor, Sridhar, and LaVoie (2017) conclude “humans tend to rely upon and use prototypes... because the access to the prototype requires significantly less cognitive effort...” (p. 1). On the other hand, the experimental group, which was not provided with samples and illustrations, designed and built more creative and diverse solutions. By removing pre-existing solutions, the students were unable to rely on others’ past design diligence and instead were dependent on using divergent thinking to generate creative solutions to the challenge.

In Scenario Two, the instructor/researchers focused on the effects of an “empathetic character” on the creation of a design. Osburn (1948) stated, “...creative form serves as a bridge by which we can put ourselves into another’s place” (p. 48). As Bonnardier and Pichot (2020) conclude, creativity increases when, “...designers learn and collect information about the needs, values, aspirations and/or frustrations of future users...” (p. 2). Contrary to the expected results in Scenario Two, the instructor/researchers observed less creativity in the experimental group who met and communicated with the “empathetic character” or the end user of the design. In fact, the control group, without the “empathetic character,” designed more divergent and creative solutions. The empathetic character was present during the design process of the experimental group, and the students may have felt pressure to focus on the specific capabilities of that exemplar. Additionally, the time constraint may have been insufficient for the needs of the empathetic character to sufficiently impact the design of solutions. Upon reflecting on the results and the research by So and Joo (2017), additional insights were identified relating to the impact of providing information to the designer. They noted that the end user or empathetic character can be used to enable creativity; however, the instructor/researchers may have in fact stifled the creativity of the students by providing firsthand, real-time interactions with an in-person “empathetic character,” perhaps making the stakes too high. Simply providing a short bio describing the empathetic character and her needs may have produced less anxiety with novice designers.

Recommendations

Twenty-First Century skills, including creativity, have proven to be more than a passing swing of the educational pendulum. Technology and engineering educators remain acutely aware of the importance of providing hands-on opportunities focused on improving students’ creativity, but as educators look for strategies to help foster creativity and innovation, their use of models should be scrutinized since, “...many classes with problem-based learning and design-oriented opportunities utilize educational practices that may lead students down procedural paths that encourage fixation” (Bartholomew & Ruesch, 2018). This research demonstrated that as soon as students visualized a design, they had great difficulty deviating from that solution. Additionally, the real-time “empathetic character” may have inhibited the students’ creativity, in an unintended way.

Conclusions

The purpose of this article is to promote the awareness of the causality between models, empathy, and creativity in the engineering design process. The instructor/researchers observed the limiting effect of model usage on the level of creativity. This was especially poignant since the focus of the *Introduction to STEM Education* classes are to equip and prepare pre-service teachers with best practices for their own eventual classrooms. While considering the fact that the short duration of the experimental treatments may have limited the possibility of causation, additional research should be conducted to examine design fixation in the classroom. It is the instructors’/ researchers’ desire that technology and engineering educators will be cognizant of the stifling effects of model usage and will take the risk of providing less scaffolding, presented as a model or image, and instead trust students’ ability to be creative and conduct their own research during the engineering design process.

Additionally, the instructor/researchers are acutely aware that more studies need to be done to examine the effects of empathy in the design process. Although during the second scenario the instructor/researchers believed that removing models and adding an “empathetic character” actor would lead to greater examples of creativity, the instructor/researchers were mistaken. In fact, the addition of the real person in the classroom led to stifled creativity and extreme design fixation in the form of too much real-world pressure and engineering design teams blatantly borrowing ideas from one another. It may be the case that the “empathetic character” actor should not be present, but rather the end-user might be described using images or a written background of their needs within the design brief.

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Leah R. Cheek is a Doctoral Academy Fellow and Ph.D. Candidate, Department of Curriculum and Instruction, University of Arkansas. She can be reached at lrcheek@uark.edu.



Vinson Carter, Ph.D., is an Associate Professor, Department of Curriculum and Instruction, University of Arkansas. He can be reached via email at vcarter@uark.edu.



Michael K. Daugherty, Ed.D., is Distinguished Professor, Department of Curriculum and Instruction, University of Arkansas. He can be reached via email at mkd03@uark.edu.

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