Employing Applied Creativity and the Engineering Design Process in the Development of K-12 STE(A)M Curriculum (Work in Progress)

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Brian LaDuca is the creator of the IDA (Ideation-Disruption-AHa!) pedagogy for Applied Creative learning, which is the study of critical theory as creative practice into innovative application across the disciplines of study. As the director of the IACT his mission is focused on empowering a forward-thinking 21st century student with the ability to confidently develop the imaginative and creative skills necessary to excel and impact today's innovative and global workforce regardless of degree focus. He also serves as the Director/Educator for the Collaboration Accelerator that involves leading the design and creative education and innovative application of an 11-week summer internship that most recently worked with Air Force Research Labs, University of Dayton Research Labs and Emerson Climate Technologies on challenges focusing on connectivity, additive manufacturing and UAS social engineering. He has presented on his research in Applied Creativity, 4D Design and Generational Theory at the Pave Conference (Arizona State University), the Lilly Conference (Miami University-Ohio), AAC&U's Ohio-PKAL, Association of Academic Museums and Galleries conference, Imagining America, KEEN, and at the 10th International Seminar on Integral Education in Mexico City in 2017. Currently, he is finalizing the first national undergraduate certificate in Applied Creativity for Transformation with co-sponsorship with University of Dayton's School of Engineering. Mr. LaDuca holds a BFA with Honors in Performance Studies from the University of Illinois, Urbana-Champaign and a BFA in Directing for the Stage and Screen from the Johnny Carson School of Theatre and Film at the University of Nebraska - Lincoln. His professional experience includes work at both his alma mater institutions, University of Notre Dame, Northwestern University, University of Chicago and most recently the University of Dayton.

Work in Progress: Employing Applied Creativity and the Engineering Design Process in the Development of K-12 STE(A)M Curriculum

Introduction

It is understood that the success of the United States' (US) economy as well as the nation's ability to address issues critical to human survival are strongly dependent on having a workforce that is Science, Technology, Engineering and Mathematics (STEM) literate.[1-10] A Carnegie Corporation commission reports, "Knowledge and skills from science, technology, engineering and mathematics – the so-called STEM fields – are crucial to virtually every endeavor of individual and community life. All young Americans should be educated to be 'STEM-capable,' no matter where they live, what educational path they pursue, or which field they choose to work."[10] This understanding paired with shocking data regarding the lagging achievement of US students in STEM, resulted in a major overhaul of educational science standards that ultimately led to the development of the Next Generation Science Standards (NGSS).[11] The NGSS include engineering and technology as learning goals and focus on the impact that engineering can have on humans.[11-13] However, many K-12 teachers do not have a good understanding of engineering practices, applications or careers.[4, 14] Furthermore, most undergraduate teacher education programs do not include engineering concepts or engineering design practices in their curriculum.[14-16] As such, teachers need to have access to high quality STEM curriculum that is aligned with the academic content standards or to professional development opportunities that will enhance their capacity and self-efficacy in engineering if they are to be successful in implementing the NGSS.

Professional development in STEM is available to teachers through a variety of engineering and educational professional organizations such as ASM, American Society of Engineering Education (ASEE), and through various National Science Foundation sponsored programs.[17-20] One such program is the National Science Foundation's Research Experience for Teacher (NSF-RET) program.[21] This program seeks to provide authentic engineering research experiences for teachers in university laboratories and to help these teachers, "translate their research experiences and new knowledge gained in university settings into their classroom activities."[21] This is typically done through the development of curriculum that is eventually shared with other educators often on the TeachEngineering website.[22, 23]

Professional and Curriculum Development through an NSF-RET Program

In 2014, three universities received a collaborative NSF-RET grant to provide materials and manufacturing engineering related research opportunities to twelve, K-12 teachers and six pre-service teachers each summer. The six-week program began with a week-long materials boot camp facilitated in conjunction with the ASM Educational Foundation. During the remaining five weeks, the RET participants did research in the lab at their host university and engaged in curriculum development, industry tours or other professional development activities. Among these professional development opportunities included a "Changing the Conversation" activity to provide the RET participants with ideas on how to attract a more diverse group of students to the

field of engineering.[24, 25] Since one of the main objectives of this program was to facilitate the transfer of the engineering research activities into the teacher participants' classrooms, a significant component of the experience was curriculum development. Similar to that described by Billiar, et al, the Engineering Design Process (EDP) was used to develop the curriculum. This allowed the teachers to have an experiential learning experience in EDP and also demonstrated how the EDP could be applied to solve problems in a variety of contexts.[26] It is important to note that with a pilot program of 18 teachers this work has an impact on approximately 2250 students.

A critically important step of the EDP is ideation. True innovation requires robust idea generation which is a highly creative endeavor, but can also be challenging.[27-30] Challenges with ideation have been observed in both engineers and teachers through past NSF-RET programs as they tried to employ the EDP for curriculum generation.[27, 30] In an effort to address this challenge, a structured ideation session was added to the curriculum development process and piloted with the teachers. This three hour session was facilitated through the University of Dayton's (UD) Institute of Applied Creativity for Transformation (IACT) ACTlab. The goal of this experience was to provide an imaginative gateway for creative exploration where the teachers could seek out new and inventive ways to problem-solve and disrupt challenges and overcome obstacles within their classrooms and in their greater institutions. The ACTlab had been successfully implemented for humanity centered design project ideation sessions for transdisciplinary groups of students at the UD.[31,32] The primary focus of the ACTlab session for the NSF-RET participants was to build a culture of teamwork and creativity, to place the teachers outside of their comfort zone and to put them in the mindset of their students as learners.

The IACT seeks to empower participants to confidently develop the imaginative and creative skills necessary for innovation. Central to ACT curriculum and pedagogy is the use of practices and processes employed across the spectrum of creative identities. In the ACTlab, participants are guided through a three step process defined as IDA to experience how the IACT outcomes of critical perspective, creative confidence and innovative application apply to their specific discipline or expertise. The first step of this process, Ideation, introduces the development of critical perspective focusing on what is and what can be in their field of study and the world they live to broaden it in creative, analytical and innovative ways. Participants negotiate and collect the various content and the 4Dimensional data, that is, sight, space, sound and emotion being presented. Secondly, participants are challenged by the ambiguity or what they do not know about the content presented, specifically the how's, whys, what's, and who's of said content; and then the final step in ideation is the tension or how they feel and what emotional and physical obstacles they might encounter with the ambiguity of the content. The second step of the process is Disruption which uses the participant's critical perspective to develop the creative confidence to see the broad and diverse set of solutions in front of them and make leaps be, trust their intuition, and chase solutions that they haven't totally figured out yet. Participants seek ways to disturb, make more conscious, and awaken other 'avenues' for ideas and solutions. This process which includes a combination of empathy and collaboration wherein value-driven learning and shared experiences provide pivot in participants thinking resulting in the diversity of compassion as an idea. The final step of the process is the A-Ha where participants begin the fearless practice of seeing the world in complex ways and experimenting with improbable materials in seeking imaginative and innovative solutions for multiple professional outcomes. In this step, the

participants generate new sets of knowledge and identify what they can transform from the original content for a result that is an unexpected outcome in their challenge or original ideas.

In the context of the curriculum development, the ACTlab facilitated for the NSF-RET teacher participants was used to provide the teachers with the opportunity to critically reflect on their ideas of what is and what could be done in their classrooms and in the curriculum they were to develop. As part of this process, the teachers were asked to identify their perspectives on a variety of topics such as: My classroom is structured or fluid; Silence in my class is good or not good; The most effective and valuable learning happens in or out of the classroom. Additionally, as part of this process the teachers participated in a challenge sharing exercise. In this exercise the teachers identified three challenges in small groups, identified how their perspectives could be used to navigate these challenges, and then passed their challenges to another team. This team then identified the most important challenge from the list and then passed that challenge to yet another team. The purpose of this exercise was to allow the teachers to experience the tension of letting go of their own challenge in order to reframe their perspective towards another challenge. This also created the emotional obstacle needed for authentic disruption and for fostering empathy in the space.

The next step was the Disruption process which provided the teachers with a radical design exercise to address the challenge they inherited from another team. Each team was given a Bag of Improbable Materials (BIM) and asked to create a prototype of a solution to that challenge. Each team then had to share their prototype with the larger group. Through this experience, the teachers were required to make use of their creativity to figure out how to convey an idea with the items in the BIM while also taking into account any their teammates experience and perspective. As such the teachers started to fuse their expertise with their growing critical perspective to develop their creative confidence and to open their eyes to a more diverse set of solutions. The radical design exercise was then followed by a "Speed Dating" exercise where the teachers generated nine value cards by responding to prompts and sharing this with others. In this exercise, the teachers were asked to respond to a prompt, discuss it with their partner and then rotate through the line to address a new prompt with a new partner. Examples of these prompts are: I believe __ is most important to my students; I want my students to understand that __ is most important when solving a tough problem; I want my students to feel empowered to change the world through _. The final exercise in the disruption process was the "Drill Down." In this exercise, the teams were required to revisit the prototype that was created by one of the other teams for the challenge that they authored. The teachers used the value cards they generated in the speed dating exercise, bundled these value cards by similar ideas, and selected the best elements of each one. Ultimately, these were used to develop a set of actionable steps that could aide in thinking deeper and more authentically about the challenge. The goal of this exercise was for the teams to reexamine their original challenge through the lens of their group's values.

Finally, in the A-Ha process, the teachers were asked to reflect on the actionable steps and reframed challenge. The teachers then had to create a new prototype that built upon the prototype that was created by one of the other teams for the reframed challenge. During this process the teachers were tasked with thinking about the reframed challenge and the influence that their values as well as the prototype created by another team had on shaping this reframed challenge.

Overall the experience was used to create curriculum development teams and to ideate possible lesson topics and engineering problems to incorporate into their curriculum.

Impact of the ACTlab on the Curriculum Development

As part of the external evaluation process for the NSF-RET program, the teachers were required to respond to a weekly evaluation regarding specific programming that occurred that week as well as their overall experience. Through this evaluation, the teachers reported engaging in activities in the ACTlab, such as the 'Speed Dating' and 'Bag of Improbable Materials' which they would use in their classrooms. One teacher commented:

"There are so many parts to the lesson plan that are crucial to make sure that the STEM education the students are receiving is a good one. It's not nearly as simple as, 'Hey students, try to build this new contraption,' and that's the end of it. The students need to know why they are solving the problem, they need to be able to research steps, brainstorm, create prototypes, build those prototypes, test them, revise them, and present them. The lesson has to allow for students to do all of those things, while also tying the project into standards that they need to learn for your specific class. There needs to be assessments that go along with the project. It cannot just be that the project met the requirements so a student gets an A. There should be rubrics and analysis questions along the way that they are answering. They need to be able to explain or present ..."

After the ACTlab, the curriculum coaches found that the groups trusted each other and observed that when curriculum ideas were being discussed that the teachers were more inclined to say "yes, and…" instead of saying "Yes, but…" The teams quickly built upon the ideas of others within their groups. As a result of this process, by the end of the six week NSF-RET process the teachers developed creative engineering design process oriented lessons and activities that were balanced with content depth at the appropriate level. These pilot ready lessons included: 1) Elementary lesson on heat, light, color, as measurement and decimal operations framed in creating the coolest doghouse using a variety of materials; 2) High school (HS) chemistry, social studies, and art lesson on creating composite materials to build better slum houses in developing nations using the natural materials; 3) HS algebra and physical science lesson on optimizing material compositions to build a case for cell phone packaging that can resist breaking when dropped; 4) HS lesson on using various foods that can generate electricity using the operations of a battery during a power outage and 5) Middle school lesson on how heat changes the atomic structure of materials by building a lighter lift for a wheelchair.

Summary

The EDP process was used to develop curriculum as part of an NSF-RET program. In an effort to address the challenges associated with the idea generation step of the EDP process, a structured ideation session through UD's I-ACT was added to the curriculum development process and piloted with the teachers. The teachers were guided through a three step process that included Ideation, Disruption and A-Ha. Feedback from the evaluations suggest that the teachers found this to be a valuable experience. The curriculum coaches observed that the teachers appeared to demonstrate a willingness to share ideas and to be more open to "crazy" ideas. The teachers were able to develop five, highly creative curriculum that are currently being piloted and edited and will be submitted to TeachEngineering for review and publication.

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