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Making Space for the Act of Making: Creativity in the Engineering Design Classroom

Abstract

Creativity continues to be an important goal for 21st century learning. However, teachers often have difficulties fostering creativity in their classrooms. Current creativity research suggests that the act of making can enhance the teaching of creativity. Hands-on engineering design lessons are ideal contexts for studying this effect. Through examining an after school science program in engineering design, this study reveals teacher assumptions about students' creativity and how classroom environments can nurture creativity. Teachers' beliefs emerge on continua of three distinct themes: making space for creativity in their classrooms, recognizing creativity in their students, and understanding the connection between hands-on activities and creativity in the context of engineering design. Suggestions for future research are discussed.

Introduction

As the US continues to strive toward building capacity for a highly educated workforce in science, technology, engineering and mathematics (STEM) fields (NSF, 2006), educational organizations have constructed frameworks that outline critical STEM literacies that need to be cultivated in K-12 education in order to achieve this goal. A common element amongst these frameworks is a focus on increasing competencies in creativity and innovation (ISTE, 2007; Partnership for 21st Century Skills, 2007). Moreover, these efforts are also encouraged for the purposes of workforce development and global competition. Increasingly, learning science researchers have shown that cultivating creativity increases interest, engagement and positive identity with disenfranchised youth (Resnick, 2000; 2002). Others have suggested that getting students to think creatively can help their cognitive, emotional, and social development (Sawyer, 2006) with the potential to lead to "good citizenship" and a better world (Sternberg, 2007). Thus, for various reasons, it is clear that creativity must play a more central role in current educational contexts. However, as Kaufman and Sternberg (2007) write, many educators feel that creativity is an innate ability that cannot be taught or is something that is "irrelevant to educational practice" (p. 55).

Several creativity theorists have suggested that teachers need help in constructing creative learning environments that make space for making within their classrooms (Jacucci & Wagner 2007; Yi-Luen Do & Gross, 2007). The study reported here is the first phase of a two-part study in which the overarching goal is to create a curriculum and instruction framework that will help teachers explicitly focus on the teaching of creativity and innovation. In this first phase, we aim to reveal teachers assumptions about creativity in the context of an engineering design project with the eventual goal of shifting assumptions and constructing appropriate learning environments in the second phase.

Key words: creativity, engineering design, hands-on activities

Theoretical Considerations

Creativity as innate vs. learned.

In the history of creativity research, there is a theoretical divide between early learning scientists who ascribed creativity as an innate quality of the learner and those more contemporary theorists who think creativity can be learned in social systems, such as schools. Early researchers often thought of creativity as an innate trait, rather than a learned skill, which originated only in art making rather than in other disciplines. For example, Dewey (1934) explains that in classrooms teachers might encounter producers (creative learners) or perceivers (non-creative learners); teachers can support the producers in their classrooms, but there is nothing they can do to make their perceivers into creative learners. Buermeyer (1954) talks of creativity similarly as he relates the creative learner to an immutable vessel, born with an innate ability to be creative. These learners receive illumination from some little understood source and come up with new ideas using similarly mysterious processes. In the work of Dewey (1934) and Buermeyer (1954), creativity is seen as a process primarily connected to art making and not as relevant to the understanding of new ideas in other disciplines.

Research in the end of the 20th century shifted our understanding of creativity as a learning process to one that informed novel thinking in all disciplines, rather than an innate trait confined to art making. As Kaufman and Sternberg (2007) contend, a creative idea, act, or object can occur in any field, as long as it is innovative or different from anything created before it, is of excellent quality (i.e., shows the amount of work put into it and thus, is well-crafted), and is relevant to the task or problem from which it was created. Latter creativity theorists have asserted that social environments can be attuned to enable such creative products, thoughts, and acts to emerge. This process of emergence has been anchored in complex systems theory to account for and describe the non-linear relationships that may impact learning and creativity. For example, seminal work by Sawyer (1999), Gardner (1993), and Csikszentmihalyi (1988) have applied a complex systems theory lens to the study of creativity in the context of education. Complex systems are systems that are not merely a sum of all their components, but multiple agents and variables that interact with each and produce non-linear effects. According to Sawyer (1999), creative learners get new ideas from the social system to which they belong. Creative acts emerge from three levels of agents—the creative individual, the field, and the domain. Researchers such as Craft (2005) support this idea and explain that in order to sustain creative learners, teachers need to create systems that nurture creative processes in all students rather than focus on certain creative individuals in their classroom. Craft (2005) also suggests that the best way to understand creativity in students is to understand the social learning systems (schools) from which they emerge.

Other researchers in the end of the 20th century connected creative processes to all disciplines, not just art. Gardner (1993), in *Creating Minds: An Anatomy of Creativity Seen Through the Lives of Freud, Einstein, Picasso, Stravinsky, Eliot, Graham, and Gandhi*, looks closely at the lives of these six creative geniuses. Borrowing from his *Theory of Multiple Intelligences*, Gardner (1993) theorizes that creativity happens across types of learners and occurs in all domains. He states that creative learning occurs in any field, and includes science learning, among other disciplines. Taking into account all the contributions of these theorists, contemporary creativity research describes creativity as a learned, versus innate, process that can occur in the science classroom.

Creativity in the science classroom

Recently, educational research has focused on how best to support creative thinking in the science classroom. Barry and Kanematsu (2008) suggest ways that teachers can create learning environments which support original thinking through multisensory and interdisciplinary approaches. Some examples they give are creating motorbikes from motors and bikes or making the best tasting juices from a variety of vegetables. In their research, learning environments are best when teachers support creative learning through hands-on activities. Burke-Adams (2007) writes that creativity is not an “intangible component” (p. 58) of the classroom, but a process that requires teachers to use tools, like digital cameras, webpages, and other forms of multimedia, to foster it. Resnick et al. (2000) argue that creative thinking in any classroom is more than just a mental act, and is one heavily steeped in the act of construction through tangible ideas and objects for the sake of innovation. Piggott (2007) argues from the context of mathematics, that it is the act of doing in the classroom that allows learners to naturally think creatively. In the context of creative thinking within engineering design, which is the domain of our study, there are obvious practical and physical constraints for learners to consider when creating new things. In an engineering design classroom, a learner changes the world by making novel things out of what materials already exist, so the act of doing happens often in these classrooms.

Implicit in these characterizations of creativity in science and engineering education is the need for teachers to provide learners opportunities to explore ideas in environments that are set up for creativity to emerge. We have termed this process “making space for the act of making.” Jacucci and Wagner (2007) describe an ideal classroom in which materials such as technologies and art objects expand collaborative communication and promote new ideas by the very act of pinning them down to finite real-world objects. Yi-Luen Do and Gross (2007) suggest that teachers should begin to conflate their understanding of the concepts of creating and making. As creativity and creating are processes that are often more mental by nature, Yi-Luen Do and Gross (2007) recommend thinking of these processes as best undertaken in the classroom as the part of a *making* curriculum of tangible objects and actions. They argue that the act of making universalizes creative processes through which creativity can be more objectively understood and, likely, better supported in contemporary classrooms. The present research supports these essential connections between making and creating. As the core work of engineering design is tied to the act of making, we believe that highlighting this connection can help teachers encourage creativity in the classroom.

Although this literature provides useful information and starting points for how to enact activities that promote creativity in classrooms, there appears to be an implicit assumption that teachers themselves will see the importance and utility for focusing time on such activities. As experienced teacher educators, we are acutely aware of the amount of time needed and difficulties involved in influencing shifts in teacher beliefs that are necessary for impact on practice (Yoon, Pedretti, Bencze, Hewitt, Perris & Van Oostveen, 2006). In this study, we were interested in uncovering what teachers understood about the idea of creativity in relation to their roles as science and engineering teachers. We were also interested in investigating how their understanding of creativity translated into pedagogical strategies in their classrooms and practice. We believe this is an important missing link in the existing literature and see this as the first phase of a two-phase process that will eventually lead to a framework for curriculum and teacher professional development for fostering creativity in future classrooms.

We developed a framework that examines teachers' assumptions regarding creativity as innate versus learned and their belief that creativity is tied closely to the act of making in their classrooms. The following questions underpin the study framework: *How are teachers thinking about the concept of creativity? How does their knowledge or conception of creativity translate into student understanding of their class? In what ways do they make space for creativity in their classrooms?*

Methods

The study took place in the context of an NSF-funded after school program (covered under University of Pennsylvania's IRB, Protocol # 805171), entitled *SPARK! Igniting Interest and Motivation in STEM through Engineering Design*. This program is delivered at six after school sites within a large urban school district in northeast USA. Students in grades 4-8 attend the program for one hour a week over the course of ten weeks during the Fall term (September – December) and again for ten weeks during the Spring term (January – May). The after school program is delivered by teachers and other instructors (described below) in conjunction with programmed professional development on engineering design approaches. Data for this study was collected over the course of the Spring 2008, Fall 2009, and Spring 2009 terms in which four project instructors were interviewed and observed in their after school settings. The content of the lessons observed during the after school observations included designing and building straw towers; performing experiments with actual oil-eating bacteria; creating chemical models out of pipe cleaners and colored beads; creating electrical circuits with potatoes and lemons; coming up with new constructions modeling the human spine using sponge, cardboard, and string; developing a new bean-bag product; and studying aerodynamics with paper airplanes.

Participants.

The four instructors who participated in the study represented a group of educators with diverse backgrounds. The first instructor, David, held a PhD in engineering and was a practicing scientist and engineer with no substantial background in teaching in the public schools. The second instructor, Peter, had a BA in architecture, work experience in finance, and was a mid-career changer with four years of experience in the public school system as a science teacher. The third instructor, Michael, had a BA in Art and was a beginning teacher with two years of teaching experience in the public school system as a science and technology teacher. The fourth instructor, Kate, had a BA in accounting, a Masters in Education, and two years of experience as a public school, third grade classroom teacher, teaching social studies, math, and literacy, but not science. The nine students (six female and three male) who participated in the study were all in 5^{th}-6^{th} grades and between 10-12 years of age. They attended the SPARK program due to an interest in science and engineering either in their regular classrooms or as a future career goal.

The sample size of this study is small (13 total participants); however, in qualitative studies like this one, sampling logic of participants (in which certain numbers of participants are required) is less important than in quantitative studies, especially when external factors in the study are similar enough, so that themes gleaned from the data collected can be compared and contrasted (Yin, 2003). All of our main participants are teachers in the same city and have been exposed to the same curricula through the SPARK program, so certain elements of training and experience have been controlled enough in the context of this study to allow for theoretical replications (Yin, 2003).

Data sources and analysis.

Multiple data sources were collected in order to reveal the assumptions about the teaching of creativity held by participant instructors. Data sources included, 22 hours of field observations with accompanying researcher field notes, 4 hours of video footage capturing instructor-student interactions, nine 5-10 minute student interviews (see Appendix for a list of student interview questions, item I), and four 10-20 minute audio recorded teacher interviews. During these interviews teachers were asked the following questions to specifically target their ideas about creativity in the classroom:

1. *Can you think of the most creative student you've ever had? What did that student exhibit?*
2. *What is creativity and innovation?*
3. *How does it look? How would you know that something or someone has been creative or innovative?*
4. *How is creativity important in the context of engineering design?*
5. *Are there any students that stand out for you as being particularly creative?*

6. *If so, can you describe something you saw them do that makes you think they are creative? Where did this occur—in the after school program or in your classroom?*
7. *Do you think creativity is an important skill to develop in students?*
8. *What do you do when you suspect a child is creative?*
9. *Do you consider yourself creative? If so, how does this creativity manifest? Take me through what it is like for you to be creative.*

The interview questions were developed and asked against the study framework as described above. Three themes of analysis were developed, discussed, and negotiated by study researchers through a review of the literature and an iterative, quasi-grounded theory[1] approach (Strauss & Corbin, 1998) in which the data sources were reviewed systematically and mined for specific themes that addressed the study questions. The previously reviewed contemporary creativity literature was most concerned with how teachers make space for creativity in their classrooms, how they recognize creativity in their classrooms, and how creativity can be used for practical purposes in the 21st century. The main analyses that produced the three continua were completed using the teacher interviews. Classroom observations and student interview responses were used for triangulation and support of the claims made about the continua.

[1] We designate our approach to data analysis as quasi-grounded as we had established *a priori* creativity categories to address the study questions; however, the content of the categories shifted and expanded as they emerged in practice to produce continua along which teacher beliefs and practices could be viewed.

Results

Three themes from the literature around space making, creativity recognition, and utility were developed by the study researchers prior to collecting data. Within each theme, teachers' individual responses represented differing ideas that could be described on a continuum of less to more alignment with current creativity research regarding creativity as a learned process rather than an innate trait and as a useful process to develop in students.

Continuum of space-making.

This continuum was constructed around data that emerged to directly respond to how teachers considered making space in their classroom for creative learning. Examples of making space for creativity might include giving students time to brainstorm and explore new ideas, not using any form of punishment for new ideas, and allowing students the space in class to explain their new ideas and constructions. Four profiles surfaced from the four teacher participants with respect to the theme of space making. Individual teacher profiles are explained and can be seen visually in Figure 1.

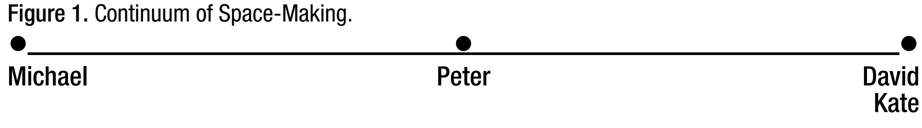
Least developed space making: Michael.

Michael expressed the least developed understanding of creativity as learned process and demonstrated the least ability to make space for it within his classroom. In interview, his responses showed a nebulous view of creativity, as he explained that a creative process was a "weird" thing to understand and was visibly uncomfortable with being questioned about it. He stated he believed that a creative student was one who did something outside of the norm and "was not afraid to take chances." He also explained that a creative student was one who was "studious." His belief that his creative students were ones who took chances seemed to have no effect on how he treated creative behaviors in his classroom. He did not support such behavior in practice as he continually reprimanded students to stay on task. He reprimanded one particular student, Donald, who clearly showed characteristics of creative behaviors to stop "fooling around." During a straw tower building activity, Donald made a connection between color of straw and straw length (for example, the red and yellow straws were shorter than the green and blue ones) and was experimenting with a new way to build the tower taking this understanding into account. In the student interview, Donald expressed the desire to construct things and showed great enthusiasm as he explained his plans to make a video game in response to the question, "Do you think you have you ever been creative?" He seemed to have space and motivation to explore creative ideas in his day-to-day life, but these tendencies were not fully realized and utilized in Michael's classroom.

Moderately developed space making: Peter.

Peter showed a moderate ability to make space for creativity in the classroom. In the interview, he stated that it is important to give students space to explain how they "came up with" their products and listen carefully for the divergent ways they could explain their new ideas. He did not reprimand any students in his classroom for anything they did in connection to their work; however, there were no students observed who exhibited any obvious creative behaviors in his class to reprimand. He gave more

Figure 1. Continuum of Space-Making.



space in his classroom for students to explain their ideas, but did not encourage brainstorming. He talked about the importance of encouraging creativity and the various ways students express their creativity in the classroom. He explained how different forms of assessment should be established for creative work, because students' work can be "creative [in] how it is expressed." His ideas about giving students space in his classroom for creative expression and explanation were in line with his practice. In classroom observations, he asked various students "how did you come up with that" as they presented their products and did not reserve this questioning for students with novel products only; however, he did not devote time for initial brainstorming. Students did not exhibit an overwhelming amount of creativity (for example, no one was as intrinsically motivated as Donald), but they were very confident in their ability to think of new things and explain their process. It might be argued that they gained this skill of explanation from Peter's classroom. One student, Betty, said that she felt that SPARK classes were helping her find "new solutions" to everyday problems. She retold a story of how she tried to envision ways to fix her family's broken television set with the confidence she had gained in SPARK to understand how machines work. While this suggests that the SPARK program itself is a great program for teaching students the ways science can help their learning and everyday lives, this is not an example of a student coming up with something new. Although it could be argued that Peter's particular selection of students might be "less creative" from an innate perspective of creativity, taking into account the learned perspective of creativity underpinning this study, this suggests that Peter's teaching only fostered moderate amounts of creative behaviors in his students.

Highly developed space making: David and Kate.

Two teachers, David and Kate, had highly developed methods of making space in their classrooms, although these methods differed between them. Their ideas about creativity were reflected in their practice, and also differed between them. David showed a developed method of creative space making, as he differentiated between creativity and innovation (in line with current theories that involve making). Based on his own practice as an engineer, David saw innovation as intrinsically tied to the tangible creations of solutions to problems. He explained, "the intangible, in creativity leads to something that's innovative, which in some ways is tangible." During the lesson on oil spills, as one student, Bill, explained his ideas verbally, David handed him over the whiteboard marker and said: "show us." In his observed classes, David questioned his students' ideas, constantly asking them to consider how their creations might measure up to real world problems. In an oil-eating bacteria exercise, he scaffolded individual work time by asking all the students to brainstorm on their own the animals that might die from an oil spill. One student, Sally, thought of developing a new kind of bacteria to clean up the oil (an example of intrinsic motivation) during the class break and David gave her space in class to both explain verbally and demonstrate her ideas by describing the bacteria on the whiteboard for the class to critique and discuss. Sally explained in her interview that creativity meant not just a "linear" solution to a problem. In an observation for a class that was focused on learning about molecules, Sally said it was important in that class to make a "different kind of shape" of a molecule. Her emphasis on the importance of not just solving the problem, but solving it in a "different" and tangible way suggested that David's space making influenced her views of creativity.

Kate showed an equally developed method and understanding of making ample space for creativity in her classroom, although her approach and ideas differed slightly. She gave time for her students to brainstorm, did not reprimand them for their creative behaviors, and gave them time in class to think of new ideas and construct them; however her methods were tailored to her personality and background (she is a third grade teacher, whereas David is a practicing engineer). When asked what made a student creative, she explained that "the one characteristic that binds them is that they are not just all waiting to hear what you want them to do" and that they all have "the ability to not want to replicate exactly what the teacher does." She viewed creativity as a step-by-step process, much like a way of developing new products in the field of engineering, in which "you brainstorm, come up with possible solutions, pick one, and test it." Creativity, to Kate, emerged from social learning. She explained regarding a shoe-making exercise,

> If you just listen to the ideas that they throw in, and reject, and build on, it's just like a constant generation of new ideas and different directions. If you just listen to that, it's like pure creativity coming out of all of them and bouncing off of each other. And that's why it makes it so hard to choose one. All of them, in that group, are just constantly generating new ideas.

Her beliefs could be observed in the way she fostered creativity in her classroom, as she sat back, in a facilitator role, and let her students brainstorm, discuss, and test out new ideas. When one student, Tom, exhibited creative behaviors such as intrinsic motivation and divergent thinking and came up with a whimsical explanation for a solution to a problem they were working on, Kate gave him space to share this idea with his group members. In class, the exercise was to make a new product out of beanbags. Tom suggested to the group that they build a very small beanbag chair for a baby to use and showed everyone a sketch of his idea. Kate asked him to explain his idea and let all group members respond before voicing suggestions to his idea. When necessary, she guided students' ideas, but never reprimanded them for any creative behaviors they exhibited. When thinking of names of their beanbag product, Tom, exclaimed "Let's call ours B.O.B. for Bits of Bean!" Kelly did not reprimand, but let the other students respond before chiming in her ideas on the name. Not limiting students' space in which to think of new things did not make their creations non-rigorous. In the student interview, Tom explained that even when you were being creative in Kate's class, you still had to make something "good."

Continuum of recognition.

Similar to the continuum of space making, teachers' responses formed a continuum of recognition of creativity in their students. We believed that it was important to investigate whether teachers were able to pick out creative students and creative acts as an indicator of whether they would later on be able to build on the creativity that existed in the classroom environment. Four profiles surfaced from the four participants with respect to the theme of creativity recognition. Individual teacher profiles are explained below and can be seen visually in Figure 2.

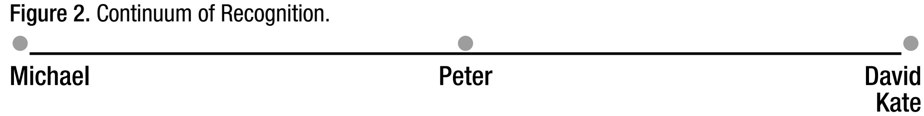
Least developed recognition: Michael.

Again, Michael showed the least developed ability to recognize creativity in his students. For example, he had a hard time naming at least one creative student in his class. Michael explained that creative students were "disciplined," "studious," and "focused." Such a view prevented him from actually recognizing creative students in his class, as creativity displays itself in a classroom often opposite of the behaviors Michael attributed to it. Instead creative learners can appear undisciplined, not studious, and not focused, as they are often busy pursuing ideas and problems that they have the intrinsic motivation to solve (rather than the extrinsic motivation provided by a teacher or lesson) (Sawyer, 1999). Also, creative learners often can seem the opposite of the attributes Michael mentioned, because they are seeking social learning opportunities (Craft, 2005). During observation, Michael reprimanded Donald, who clearly exhibited characteristics of a creative learner with strong intrinsic motivation to pursue his own part of an electricity project and seek out social, collaborative learning with his peers. In this class, students were asked to attempt to generate an electrical current from potatoes. Donald appeared to have an advanced knowledge of electrical principles prior to any knowledge given in the class. For example, he understood the difference between open and closed circuits before the teachers explained this idea to the rest of the class and contributed to their beginning lecture. In the beginning of the circuit building part of the lesson, he had an idea to connect the potatoes in a new way. When Donald tried to explain his ideas to his group members, Michael told him to "stop bothering the rest of the group and get to work!" Michael also connected creativity heavily to art making in his interview and did not see creativity as a learning behavior across disciplines. When asked "Do you consider yourself creative?" he responded, "I was an art major in college." When asked "How does this creativity manifest?" he explained, "Paint, sculpture" that was made through an unclarified source of "inspiration." This connection of creativity as tied to art making and as something that involved inspiration prevented him from seeing the creative behaviors of students who were making new objects in his engineering class as creative and novel products (Gardner, 1993), as these objects were not part of an artistic discipline.

Moderately developed recognition: Peter.

Peter showed a moderate amount of creativity recognition. He was able to specify some creative learners, but tied this specification to students who were able to give a narrative of their creative process. He explained that his creative students were ones who were "looking inward for ideas" and "love the hands-on, coming up with something." This echoed current thinking on creative behaviors, as creative students show intrinsic motivation (Sawyer, 1999) and are naturally creative in hands-on activities across disciplines (Gardner 1993; Jacucci & Wagner, 2007; Yi-Luen Do & Gross). Peter saw creativity as related to verbal expression and intelligence, asking students how they "came up with" their products. He was able to recognize that creative students often had divergent thinking and tried to make space for all his students to potentially exhibit their thinking verbally. He believed that a creative student could work at a task enough to finish the project sufficiently and explain their thinking and that this explanation was part of the creative process. While this helped Peter have the increased ability to potentially recognize creativity in many students as he could examine their thinking and look for novel ideas, there is no current

Figure 2. Continuum of Recognition.



literature that determines a correlation or relationship between creativity and the ability to explain it. Given Sawyer's (1999) definition of intrinsic motivation, creative learners are sometimes too driven to think of new ideas to also think of ways to explain them. This added stipulation could prevent Peter from recognizing creative students who might not be able to engage in this part of his requirement or assumption. In the future, he could miss creative learners and potentially not support their thinking.

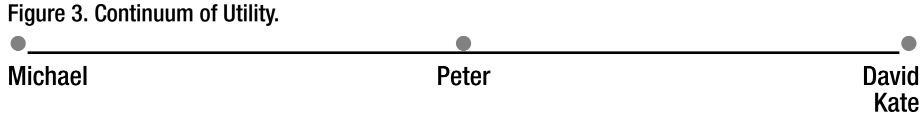
Highly developed recognition: David and Kate.

David had a highly developed understanding of creative students. He explained that his creative students were not necessarily the most traditionally academic ones and not the ones who were necessarily concerned with "getting the answer right." David believed similarly to creativity theorists Kaufman and Sternberg (2006) that traditional forms of intelligence could be sometimes unrelated or even a hindrance to thinking in new ways. This belief seemed to be instilled in one of David's students, Sally, who explained that she wanted to always think of "new ideas" in her future career as a doctor. Kate had an equally developed understanding of recognizing creative students. She viewed creativity as not tied to one discipline (Gardner, 1993) and said that in her class she has "had creative kids who were very artistic… creative kids who just want to do math problems…creative kids who just want to write stories all the time." She viewed all of her students as having the ability to be creative, as creative learners are simply "thinking of ideas that wouldn't be the first thing that would come into my head." She supported new ideas in her classroom that may or may not have been different from her own. She gave students ample time to brainstorm and did not shut down any new thinking, but simply guided their thinking occasionally with open-ended questions. For example, she recognized that creativity emerges from social systems and explained that to find an example of creativity in her classroom, one should "just listen to a conversation between the students." This belief was echoed in her practice, as she recognized the creative learning in her classroom, and supported it by letting it grow on its own. One of her students, Ann, exhibited the benefits of Kate's recognition of creativity resulting from social and collaborative learning. In her interview, she mentioned her excitement about the vertebrae project, in which the goal was to think of new ways of constructing vertebrae models. She explained that she sought the help of her family in solving the problem outside of class, because she could not stop thinking about a possible solution. It is possible that Kate helped to incite these thoughts and fostered Ann's thinking towards many novel solutions.

Continuum of utility.

We applied a third continuum to interview and observation data with the theme of utility. This continuum relates most to how important teachers saw the act of making new, tangible products in the classroom and how useful they thought creativity was to the generation of new, practical products in the world. Some examples included the propensity of teachers to connect creating to making new products and to support their students' making of novel objects in the classrooms. All four teachers were asked how creativity related to engineering design during their interviews and their responses were coded on this theme of utility.

Figure 3. Continuum of Utility.



Least developed utility: Peter.

Peter showed the least developed understanding of how important the creation of novel products was in the engineering design classroom, as he explained that the "creative thought process" was more important for teachers to uncover than the creation of novel and practical products. When working with students, he did not pay much attention to the actual objects they were creating, but instead engaged with their ideas and thought processes. This conceptual rather than practical view of creativity in his engineering design classroom resulted in a lack of finished objects, as his practice did not support the importance of creating new, practical objects to solve real world problems. This approach could be seen in interviews with his students. One student, Terry, explained that a project she was working on at home relied heavily on ideas rather than the creation of practical, novel products. As she explained her home project, she said: "I was just putting pieces together just to see what to do and that's what came to my mind—a music box." Her creation of a music box was not based on the motivation of utility and was not a practical solution to a real world problem. Instead her idea to build a music box resulted in building a novel object with no real world function. Her music box was an object that required verbal explanation to understand rather than being able to stand on its own, as novel object solutions to practical problems can do. It could be argued that Peter's teaching of creativity as linked heavily to "thought process" and explanation informed Terry's choice to make an impractical novel product versus a practical one.

Moderately developed utility: Michael.

Michael showed a moderate understanding of utility, as he explained that creativity was important to foster in engineering design to solve real world problems. His response to the interview question "How is creativity important in the context of engineering design?" was, "For example, when they build tunnels under rivers and stuff, how they get the tunnels to do that, keep the rivers from flooding. How they accomplish these tasks requires a lot of creativity, thinking outside the box."

Even though his assumptions were in line with current research (Jacucci & Wagner, 2007; Yi-Luen Do & Gross, 2007), his practice did not echo these ideas. In classroom observations, he was most concerned with a linear process of going through the lessons, without incorporating a space for novel knowledge creation into his lessons. When students had new ideas or questions about particular parts of the lessons and the practical implications, like Donald often did, he told them that they needed to "move along" to get through the lesson. He did not connect issues of real-world utility to the objects his students were creating and left no time in class for exploration and reflection of these issues. When creating straw towers, he made no reference to how the straw towers were models of real buildings. During the electricity exercise with potatoes and lemons, he made no reference to how the circuits the students were building were like those found in their homes or in other real world locations to which the students might relate. There was a disconnect between the objects being created in class and real world issues.

Highly developed utility: David and Kate.

David had a highly developed understanding of utility, as he described the real world problems facing us today (such as water shortages and infrastructure issues) and the need to tie innovation in the classroom to the act of constructing physical products to create both long-term and short-term solutions. As a practicing engineer, he was able to deepen many of his lessons with real-world problems. He explained that an added benefit of connecting engineering and creativity was that "kids innately like to build, and test, and that's what you do as a scientist and as an engineer." Kate also had a well-developed understanding of creativity tied to utility. She defined creativity as "unexpected and functional." She saw creativity as a first step in solving real-world problems and thought that if you are not being creative, "You are just doing what's been done before." She also explained how the imaginative world could come into play during the creative process. However, she suggested that by tying the creation of new ideas to novel products in the real world, teachers could be more effective in the classroom. In her interview, she explained,

> We are so crunched for time in schools these days. I think there are ways to do that for real problems that would apply across the curriculum. So, although the kids want to do it for things like their imaginary shows they are watching on TV as well, I don't think those are things I would go to. There are so many connections that have to be made in things we have to cover, that there are ways to pull out those things in problems that could really apply.

This echoed the beliefs of her students interviewed by the study researchers. One student, Ann, said that being creative meant "making things." She described a lesson in which the class made shoes and she talked about how important it was during this creative process to make sure your foot was protected from the elements. In her classes, Kate tied innovation to practical problems and encouraged her students to be creative as they constructed new, tangible products with real-world practicality.

Discussion

Teachers fell along the three continua in varying ways. Michael was least developed along two continua (Space-Making and Recognition) and Peter was least developed on the Utility continuum. Kate and David were highly developed along all three, but for different reasons. Background or years of teaching experience had no effect on how teachers fell on the continua. Kate and Michael had equal years of teaching experience, but behaved very differently when students exhibited creative behaviors in their classrooms. In addition, Kate was an accounting major in college and Michael majored in art, which might lead one to think that Michael would be more accepting of creative behaviors (as art is traditionally the discipline associated with creativity) and show more space-making ability in his classroom; however this was not the case. There was a mismatch between background and teacher space making for creativity.

In terms of creativity recognition, how participants' ideas of creativity related to the ability to understand creativity as a learned process rather than innate and related to the act of making is important to consider. Sawyer (2006) explains that people often become uncomfortable when discussing creativity as they feel there is something intrinsically magical to creative acts that should not be dissected. This mimicked Michael's discussion of creativity, as he became visibly upset when he remarked that the interview questions were "weird." He also saw creativity as closely tied to the artistic disciplines and did not support the science learners in his classroom who were clearly exhibiting creative learning processes. In the case of Michael and Peter, they both seemed to have an understanding of creativity as an innate trait, rather than a learned process that they could foster in a classroom. Peter's ideas of creativity as largely a theoretical construct showed the way that even the best meaning teachers can sometimes make creative learning hard to practice in the classroom. Peter's ideas of creativity, for example, are difficult to transfer among classrooms with different students and disciplinary goals, as they are steeped in creativity as a set of ideas, rather than as tied to the creation of useful, novel products.

Kate and David saw creativity as a learned process that was useful to the real world. David thought of creativity as having representation in the material world through the creation of novel products. Katie connected creativity to real world problems that needed to be solved and saw this connection as an efficient way for teachers to apply creative learning practices to their classroom. Kate's and David's ideas about creativity and practices were more in line with current creativity research than Michael's and Peter's. Kate tied creativity not to only one discipline, like art, (Gardner, 1993) and saw the creation of new ideas in learners as emerging from social systems (Sawyer, 1999; Craft, 2005). In an actual classroom, both Kate's and David's views are most helpful in fostering creativity, as they give a finite reality to students' ideas and create new products that can be used to the world to solve real problems. They most relate to recent creativity research (Jacucci & Wagner, 2007; Yi-Luen Do & Gross, 2007), which suggests the act of making objects in the classroom is the best way to help students think creatively. In order to follow the recommendations geared toward 21st century learning skills, it is prudent to consider the ways in which teachers already foster creativity and innovation. Future studies will look more closely at these study participants and more teachers in order to uncover how teachers can best make space for creativity.

Educational Implications

As teachers ideas about creativity have direct influence on the choices they make in their learning environments, it is important to investigate the similarities and differences between what theorists think are the best methods for fostering creativity and what teachers are actually doing in the classroom. This study demonstrated that teachers can bring a variety of perspectives to their classrooms and that there are different ways they can encourage creative learning. This study adds value to the existing research by suggesting that the creation of learning environments that promote *making* can be a good way to engage students in creative thinking in the classroom. Making space for the act of making in classrooms is ideal because it resists a uniformity of answers among students and naturally engenders new ideas in classroom learning environments. In the second phase of this study, we intend to create a curricular intervention that will help to counteract teacher assumptions about creativity that potentially stifle its growth.

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