Creative Education, 2017, 8, 255-271
http://www.scirp.org/journal/ce
ISSN Online: 2151-4771
ISSN Print: 2151-4755

5th - 7th Grade Girls' Conceptions of Creativity: Implications for STEAM Education

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How to cite this paper: Tsurusaki, B. K., Tzou, C., Conner, L. D. C., & Guthrie, M. (2017). 5th - 7th Grade Girls' Conceptions of Creativity: Implications for STEAM Education. *Creative Education, 8,* 255-271.
https://doi.org/10.4236/ce.2017.82020

Received: December 19, 2016
Accepted: February 24, 2017
Published: February 27, 2017

Abstract

Creativity is at the heart of both art and science, yet art is commonly viewed as more creative than science. A STEAM (science, technology, engineering, art, and math) approach to education has the potential to increase understandings about creative practices and dispositions that are common to both fields. In this paper, we examine how 5th - 7th grade girls attending a summer STEAM academy viewed creativity in both art and science. We draw on existing concepts of creativity, with a focus on the 4P framework (person, press, process, product) (Rhodes, 1961), to frame and explain similarities and differences in the girls' notions of creativity. We found a number of similarities in views about creativity in art and science, as well as some important differences: Girls view creativity as it relates to art as associated with the person, while they more often view creativity as it relates to science as associated with specific practices or processes. Further, the girls viewed art, and creativity in art, as essentially an unstructured enterprise with no rules. We discuss the implications for STEAM instruction that can help support the development of authentic views of creativity in art and science, which in turn may foster interest and engagement with both fields.

Keywords

STEAM Education, Creativity, 4Ps, 4Cs, Art, Science

1. Introduction

Integrating art with STEM, or STEAM (Science, Technology, Engineering, Art, and Math), has gained tremendous popularity over the last several years, in large part due to the assumption that this approach positively impacts a suite of outcomes associated with science learning. While STEAM as a research field is still young, there is emerging evidence for significant impacts on youth. For instance, the maker movement, in which learners design STEAM products such as Arduino-based textiles, music produced through circuit blending, or sculptures produced by 3-D printers, has yielded evidence of deepened engagement in STEM practices (Brahms, 2014). It has also been shown to increase the development of interest, identity, and STEM content knowledge (Vossoughi & Bevan, 2014) and to promote design thinking (Peppler, 2013; Norris, 2014).

STEAM education is premised on the idea that there are deep overlaps between the practices of art and science, and these overlaps represent an opportunity to show the "trans-disciplinary" (Root-Bernstein, 2003) nature of thinking—especially of creative thinking—that can occur when one thinks across disciplines rather than within single disciplines. Art and science share many overlaps in terms of both common practices and habits of mind. Visual-spatial thinking is key to understanding the structure of molecules, the actions of enzymes, and the 3-D structure of galaxies (Ramadas, 2009). Visual-spatial thinking is heavily used to model abstract scientific concepts (Walker et al., 2011) and is also widely recognized as a central aspect of creating art (Kozbelt, 1991). Artists form mental images of space, line, color, and shape before committing these images to paper or other mediums (Walker et al., 2011), and they excel at visual-spatial tasks such as mental rotation, visual analysis, and form recognition (Kozbelt & Seeley, 2007). Experimentation also takes place across both the sciences and art—scientists form hypotheses, record results, and communicate those results to the public. Similarly, artists experiment with mixing colors, various painting or sculpting techniques, and publicly show their work in galleries or art shows. Fulton & Simpson-Steele (2016) outlined practices common to both science and art, such as noticing, wondering, visualizing, and communicating. Both the *Next Generation Science Standards* (NGSS) (NGSS Lead States, 2013) and *The National Coalition for Core Arts Standards* (NCCAS) (NAEA, 2013) also outline major practices that are inherent dimensions of each discipline, such as investigation, experimentation, and observation.

Creativity is also at the heart of both art and science. In fact, Root-Bernstein (2003) argues that "the ways in which artists and scientists discover and invent problems, experiment with ways to come to grips with them, and generate and test possible solutions is universal" (p. 268). However, despite the momentum of STEAM education efforts, science is still seen largely as rigid and dispassionate, while art is seen as more creative (Mishra et al., 2012; Henriksen, 2014). The question then arises of how we can utilize innovations such as STEAM to encourage perceptions of creativity across disciplines that reflect the authentic practices of each.

In this paper, we examine how 5th - 7th grade girls attending a summer STEAM academy viewed creativity in both art and science. We ask the following questions: (1) what views of creativity do the girls have, and how do they differ between art and science? (2) what do their views of creativity in art and science tell us about their understandings of the disciplines? and (3) based on these findings, what are implications for teaching about creativity in both art and science in order to support trans-disciplinary learning across art and STEM?

In what follows, we first frame our work with a review of conceptions of creativity that we draw on and how we operationalize creativity using the four P framework (Rhodes, 1961). Then, we share the results from two years of data, 2015 and 2016, of 5th - 7th grade girls' conceptions of creativity as they relate to the four P framework and the similarities and differences in how girls described person, process, product, and press across art and science. We document the range of ideas that girls have around creativity as it relates to the four Ps and to art and science. In the discussion, we examine themes that point to differences that girls see in creativity when specifically linked to art or science, and in turn, larger issues about how the girls view art and science as domains. Finally, we discuss the implication of this work for STEAM instruction.

2. Framing Creativity

2.1. Conceptions of Creativity

Creativity is a difficult concept to define and has been studied from individualistic or personalities perspectives, cognitive perspectives, and sociocultural perspectives (Sawyer, 2012). As there are many conceptions of creativity, we provide a review of common conceptions of creativity that we use to guide our work. A common framework for conceptualizing creativity is the idea of big C and little c creativity. In big C creativity, creativity is the generation of a product that is judged to be novel and also to be appropriate, useful, or valuable by a suitably knowledgeable social group (Sawyer, 2012). It is reserved for significant historical achievements, such as those made by recipients of prestigious awards such as the Nobel Prize, National Medal of Science, Pulitzer Prize or other top awards and accolades in their respective domains. According to Csikszentmihalyi (1997):

> Creativity is any act, idea, or product that changes an existing domain, or that transforms an existing domain into a new one. And the definition of a creative person is: someone whose thoughts or actions change a domain, or establish a new domain. It is important to remember, however, that a domain cannot be changed without the explicit or implicit consent of a field responsible for it. (p. 28)

Csikszentmihalyi emphasizes that creativity is observed in the interrelations of a three-part system that includes the domain, field, and person. The domain, such as science or art, consists of a set of symbolic rules and procedures. The field includes the individuals, who in visual arts include curators, art critics, art teachers and others, who act as gatekeepers and decide whether a new idea or product should be included in the domain. It is the person, the third part of the system, who uses the symbols and procedures to produce something that is deemed creative by her/his field. Studies of big C creativity tend to focus on creative people, their work and how they have been creative through moving a domain forward in new and different ways (e.g., Csikszentmihalyi, 1997; Simonton, 1994; Gardner, 1993).

While big C creativity is associated with famous, well-known people, little c creativity can be found in most people (Kaufman & Beghetto, 2009). Little c creativity, often referred to as everyday creativity (Sawyer, 2012; Beghetto & Kaufman, 2007), is associated with creativity that takes place during routine activities that people perform in their daily lives, such as when a person comes up with a new cooking recipe or a variation on a piece of music. Theories and research that focus on little c creativity investigate how people use creativity and its importance in daily life, and how creativity is not relegated to a few individuals within society, but rather widely distributed (Kaufman & Beghetto, 2009).

While big C and little c creativity are two conceptions of creativity, Beghetto and Kaufman introduce "mini-c" and "pro-c"[1] creativity to capture other instances of creativity not embodied by big or little c (Beghetto & Kaufman, 2007; Kaufman & Beghetto, 2009). Beghetto and Kaufman "…define mini-c creativity as the novel and personally meaningful interpretation of experiences, actions, and events." (Beghetto & Kaufman, 2007: p. 73). Unlike big C and little c creativity, which rely on external validation, mini c creativity is an interpersonal judgment. It highlights how creativity plays a role in the learning process. Mini c is useful for considering, for example, the creativity of students and how teachers can foster creativity, and allows for personal creativity or learning of something novel that others may already know or understand. Furthermore, because mini c relies on intrapersonal learning, it broadens conceptions of creativity that may only recognize external products.

> Indeed, as Vygotsky (1967/2004) noted nearly half a century ago, "any human act that gives rise to something new is referred to as a creative act, regardless of whether what is created is a physical object *or some mental or emotional construct that lives within the person who created it and is known only to him*" (emphasis added) (As cited in Kaufman & Beghetto, 2009: p. 4)

Mini c accounts for creative potential and processes rather than examining or placing too much emphasis on outcomes, as little and big C do.

Mini c fills a gap in the creativity framework for understanding the role that processes and intrapersonal learning play. However, big C, little c and mini c do not account for individuals who are professionals, but have not yet reached the status of big C by contributing revolutionary products to their field. Pro c fills this gap by providing for a professional level of expertise in a creative area. It presents those who have moved beyond little c, but have yet to obtain, or perhaps may never obtain, big C status. Pro c requires training, production of a product (e.g., book, painting, invention), and is externally validated and domain specific. See **Table 1** for a summary of big C, pro c, little c, and mini c conceptions of creativity.

[1]Beghetto and Kaufman (2007) use hyphens as they name the 4cs: "mini-c", "little-c", "pro-c", and "big-c", but this notation is unique in our searches of the literature. For clarity, we will not use the hyphen as we describe the 4Cs.

Table 1. 4 Cs of creativity.

Conception of creativity	Description	Domain specific	Product that is externally validated
big C	Very few people and/or products considered big C creative; reserved for those who make historical achievements	Yes	Yes
pro c	Professional level of expertise in a creative area; requires training	Yes	Yes
little c	Everyday creativity found in most people	Usually	Yes
mini c	Personally meaningful creativity; highlights the role that process plays in creativity	Not required	Not required

2.2. 4 Ps: A Way to Operationalize the 4Cs

Closely related to the 4 C framework is the 4 P framework (Rhodes, 1961). Csikszentmihalyi (1997) emphasizes that creativity involves a three-part system including the domain, field, and person, all of which are key features of big C creativity. However, domain changes are not associated with mini c or little c creativity. The 4 P framework operationalizes elements of creativity through a focus on product, person, process and press. Product refers to products (inventions, new drug treatments, original pieces of art) that are judged novel and appropriate by the field. Person refers to personality traits or types associated with creativity. Process involves the processes during creative work or creative thought and press refers to the environment or context "acting on the creative person or process, such as the social and cultural context." (Sawyer, 2012: p. 11). In our work, we focus on perspectives of creativity that take into account interactions between press, person, process and product. Big C, pro c, and little c all emphasize products that are created by people, while mini c recognizes creative processes of people, or learning that may be new to the person but not new to the domain or field. Rhodes (1961) argues that "what is happening here is that a word which should be reserved to name a complex, multifaceted phenomenon is misused to name only one part of a phenomenon...But creativity cannot be explained alone in terms of the emotional component of the process or in terms of any other single component" (p. 306). Thus, creativity works as a complex system where each of the Ps interacts with the other and "overlap and intertwine" (p. 307). This study leverages the 4 P framework as a tool to classify and examine girls' beliefs and ideas about creativity as it relates to art and science. In contrast to descriptions of creativity that draw from experiences and reflections of notable creative minds (c.f., Root-Bernstein, 2003; Csikszentmihalyi, 1997), this study draws from empirical interview findings of over 100 5th - 7th grade girls to provide a rich description of how they view creativity in art and science. Thus, we add a data-driven perspective to documenting how views of creativity relate to views of the disciplines of art and science, and what that can tell us about designing learning environments that support trans-disciplinary learning.

3. Methods

3.1. Context

The context for this study is a two-week summer academy for 5th-7th grade girls called *The Colors of Nature*. Data for this study were collected in the summers of 2015 and 2016. The academy ran for two sessions for two weeks each, once in a large urban city in the Southwestern United States and once in a small city in the far Northwestern United States. The focus of the academy was "the colors of nature", focusing on the function of color in biology (that is, the reason why the color evolved) and its overlap with art, how color is produced (optical science and its overlap with art), and how the practices of science overlap with the practices of art (observation, experimentation, recording procedures, taking notes, analysis, publicly presenting scientific/artistic results).

The academy was designed around a series of design challenges, purposefully designed to integrate science content and practices with art projects and practices. For example, after learning about the various reasons that organisms have evolved colors (camouflage, mating, startle, etc.), the girls planned out and designed a stop-motion animation video where they chose one function of color and depicted it in some way in their video.

Researchers assumed the role of participant-observers, sometimes interacting with youth during activities, conducting interviews with participants, videotaping sessions, and taking field notes. Data sources for this study include interviews and art/science attitude surveys. Each participating girl was individually interviewed by one of the researchers. The interviews were audio-recorded, transcribed and analyzed. The paper surveys were completed by each girl at the beginning of the academy and then transcribed and analyzed.

3.2. Coding

After coding each interview across the two academies for two summers (n = 120), we analyzed the utterances that were coded for both science and at least one of the 4 Ps to look for patterns in how the girls described creativity in the context of scientists and their work. We then did the same analysis looking at utterances that were coded for both art and at least one 4 P code. We also analyzed survey data (n = 116), where the girls were asked to describe characteristics of scientists and artists. We examined how often girls described scientists and artists as creative in the surveys. While we draw on the survey data to show differences in how often girls ascribe creativity to scientists or artists (Person), in the following sections, we present findings that illustrate the range of ways that girls perceived creativity in art and science, and the insights that these perceptions of creativity gave us into the girls' views of the nature of the disciplines of art and science. We argue that this contributes unique descriptions of perceptions of creativity that serve to operationalize the 4 Cs in terms of the 4 Ps.

4. Results

In this section, we will present results from the interviews and art/science surveys in order to provide a rich description of how the girls view creativity in art and science. We organize this section around the 4 Ps and then analyze the findings in the following section.

4.1. Person

Girls often described creativity as a trait, or associated with a person. One girl described creativity as, "Where you have a good mind and you're good at making things and you are very creative. You have good ideas about different things and you do it and it's creative." Creativity is part of who a person is; it is part of their mind.

Girls completed surveys that included open-ended questions asking them to list four descriptors of scientists and artists. Table 2 shows the percent of responses from the 2015 and 2016 surveys that included "creative" in one of the four slots for either scientists or artists.

Only 17.24% of the girls listed "creative" as an attribute of scientists, while 54.31% listed it as an attribute of artists. The girls were also asked to describe artists and scientists in their interviews. When girls talked about creativity as a trait, they typically said it was something that an artist or person had. For example, when one girl was asked to describe an artist, she said, "An artist is creative, helpful, energetic, creative." Similarly for science, a girl described a scientist as, "They're smart. They're creative. They're problem solving…" The girls listed creativity as a trait, similar to other traits such as being smart, kind or fun. They talked about creativity as a trait of a person in general terms, which suggests that this trait could be found in a person at the mini c, little c, pro c or big C creativity. Sometimes the girls mentioned a specific artist or scientist and described her/him as creative. For example, one girl, when asked to describe a scientist, said:

Interviewee: I always think of Bill Nye.

Interviewer: Bill Nye the Science Guy, okay.

Interviewee: Because he's like fun, creative… and he shows how to do science in different ways, like he'll give one example the way he would do it and then he would have someone else—like he would do it the way someone else would do it like a kid would do it just to be fun.

Bill Nye hosted a television show in the United States called, *Bill Nye the Science Guy*, and his creativity may be considered by the field as pro c creativity. Girls also mentioned scientists such Einstein and artists such as Van Gogh and Picasso, who would be judged by their respective fields as having big C creativity, as they moved their respective domains forward in meaningful ways.

Table 2. Girls' association of creativity with scientists and artists, 2015 and 2016 results combined.

	% responses (n = 116)
Scientists	17.24
Artists	54.31

While the girls mentioned creativity with relation to artists and scientists, they did not expand upon the trait.

4.2. Process

We defined process as actions that artists and scientists engage in during creative activity. Rhodes (1961), when originally conceiving of the 4 Ps, imagined process to involve "motivation, perception, learning, thinking, and communicating" (p. 308). These were the processes in which "inspiration" occurred, as well as the processes by which one "convert[s] an idea into an object or into an articulated form" (p. 308). We divided processes into specific actions, including innovate, discover, construct, and experiment. While the girls discussed practices such as "experiment" and "discover" in other contexts during the interview, process codes were only used when specifically in the context of discussing creativity.

When girls used the word "innovate", they referred to practices where an artist or scientist improved upon a pre-existing method. For example, one girl said, "let's say they [scientists] have a really hard question or science problem they're trying to solve and they don't know the answer to it. So, they use other scientists' method and then they turn it into their own method." Similarly, another girl said, "I think that even though they're scientists and they're working really hard to like create the future basically, they're also doing things creatively, like thinking like how can I make this better?" In these examples, scientists are seen as using creativity to take existing methods or situations and iterating on them to make them their own or improve them. Innovate in art was seen similarly, when girls discussed taking existing lines or shapes and making them into something new: "they can turn a line into something else creative like a unicorn."

Discover was a process that was never coded for artists. For scientists, the girls mentioned that scientists needed creativity to think differently in order to make discoveries: "if they [scientists] were to go out and then discover—try to discover something new, they would have to think in their mind and be creative of what they might discover. Another girl said, "They have to think differently. To find out something new, they have to be thinking different than everyone else." We think it is interesting that discovery was not reported as a part of the creative process for the girls, even in the context of mini c, or personal discovery of new art techniques or mediums, especially as our observations of the girls during the academy were not consistent with this view. We documented moments of mini c-related discovery: of how ink would fall in water, how pigments affected each other, and of certain properties of materials for projects. We think this was more to do with the language of "discovery" usually being more connected with processes in science than with art, but this also gives us insight into how disciplines can be viewed differently despite significant overlaps in practice.

Construct was coded when the girls described the process of using creativity to build something. For example, one girl said of artists, "I think that when you make something new and it's never been done before or it's just something that popped up in your head, and I think that's the most creative part of doing art."

Another girl said of scientists, "They're creative and problem solvers. They have to think a lot and think of new ways to do things to make something happen or to fix something or to make something new." In both of these cases, scientists and artists use creativity to make something completely new.

Experiment was coded when the girls described the processes of testing or experimenting in either art or science. One girl said of scientists, "they have to like create what they're gonna be experimenting, so they have to have an idea of what they're gonna be doing, and so they have to be creative to figure out what they want to find out. Similarly, another girl said of scientists, "They test things out and they experiment with different things, like maybe they use chemicals to figure out a new type of medicine that can cure a sickness a disease, yeah, like test things out." Of artists, one girl said, "They need to like experiment with different colors and mixing them." In all of these examples, creativity is used in the process of either coming up with an experiment or in the experimenting itself.

In both science and art, the girls mentioned that creativity can be used to solve problems. This view of the role of creativity in science and art closely reflects the engineering practices in the *Next Generation Science Standards* (NGSS lead states, 2013) that focus on defining problems and coming up with solutions to those problems. In fact, the engineering design process (Jenkins, 2015) reflects very similar practices outlined in the national visual arts standards (NAEA, 2013). Both articulate processes of brainstorming multiple solutions or approaches to a problem or creating a work of art, researching constraints on a problem or with materials, and presenting or communicating about your solution or piece of art. Examples from the girls included:

Art

- If you didn't have equipment to answer your question, you would be creative and find another way.
- They [artists] have to be creative, like, if—also if something doesn't go right. Like, they accidentally mess up, you have to be creative to fix it. You know, like, just pretending it's something else.

Science

- They [scientists] have to be creative, like if something doesn't go right they have to be creative and find a new strategy and find a new way.
- If something doesn't go right they have to be creative and find a new strategy and find a new way.

4.3. Product

According to a big C, pro c, and little c definitions of creativity, there needs to be some type of product that can be judged by an appropriate community as creative. Similarly, girls described creativity as associated with a product, saying, "I would say that creativity is just kind of like making unique things that haven't really been done before…" and "Creativity is something that you make and someone call it creative, it will be—say, if you made this tablet, a person who made this tablet is creative. Creativity. That's creativity." While some girls associate creativity with products, some go further in their descriptions, explaining that the products are unique, different, or new from what has been done before.

When specifically talking about art and creativity, the girls mentioned products, such as pieces of artwork, when they discussed creativity. For example, one girl said:

> There are sculptures and thinking of stuff that's different. For you to make money, you can't just draw something that's boring and is like a painting that's white with no creativity. No one would buy it because it's just white. It's just dull. If it is really different and cool, I feel like you'd get more sellers because it's more creative and different. People like different, I think.

She associated creativity with a product that one might buy. She also explained that a product is creative when it is different. Similarly, another girl talked about how artists are creative because they are creating a product that is new or different. "Yes, artists do almost all of the time, unless they're recreating a piece exactly. But, I think that when you make something new and it's never been done before or it's just something that popped up in your head, and I think that's the most creative part of doing art." One girl described the importance of art as fostering creativity:

> Well, I found out art is getting cut, and I was like, What!? 'cause seriously! I think if children, if they spent more time and money, if they spent more of the budget it into music and art, then children would discover that creativity, and they can invent more stuff.

Even as she argued for the importance of art in schools, she talks about creativity as leading to a product. She said that "they can invent more stuff."

Just as they talked about creativity in terms of products in relation to art, they also talked about products in terms of science. One girl said, "they have to be creative to think of new things that they need to figure out and stuff like that," while another stated, "Because scientists use different tools and stuff and they might put two tools together to make a different tool." Yet another girl associated creativity with coming up with a new medicine, explaining, "Well, I guess because if they're like mixing—like if they're like making a different kind of medicine they'd have to be creative to create to help defeat the sickness that you have." Scientists create "new things", tools, medicine or other products. Some girls associated the products with things that would help people, such as medicines or tools.

New ideas: While some products were physical, products were sometimes described as new ideas. For example, one girl talked about creativity as, "being able to come up with your own unique ideas." When specifically talking about art, one girl described her own creativity as, in part, the ability to come up with ideas. She explained that she likes art because:

> It's just a good old way to express me and how—like, my mom always says how I'm creative and sometimes I don't—when I can't think of ideas it fru-

strates me, but then I just keep going and I eventually have an idea. Like I just do the first thing that comes to my mind and try it out and if I don't like that I brainstorm more ideas.

To her, an important aspect of creativity was the ability to come up with ideas. Similarly, in science, one girl said, "Yeah, you can't come up with new ideas if you're not creative. I mean, if you're not creative, then maybe we wouldn't have plastic or this couch, or maybe we wouldn't even have windows." Another girl stated, "Yes, because they have to, like, think of what they wanna do and then they have an idea and then it can be a really creative idea." While a new idea may be considered a creative product in itself, it is also part of the process, the starting point, to making a creative product. One girl explained that she liked doing science because, "I get excited testing new things to develop. New ideas. Just be creative and thinking about new ideas to develop new things. Like how the ice cream was made or the microwave." In other words, creative, new ideas, lead to the development of new products. Products are an essential feature of big C, pro c and little c conceptions of creativity, and can play a role in mini c creativity. Products—whether they be tangible and concrete, or the application of new techniques or styles—are necessary, as they are the aspect that is deemed creative by the field.

4.4. Press

Press can be viewed as the context or environment in which creativity takes place (Sawyer, 2012). One example of press we found was when a girl described her relationship with her sister.

Interviewee: I think my sister is a scientist because she is really creative every day because every day when I come home she tells me do you want to do arts and crafts, or do you want to help me or I could help you design your room more and I said okay and she just is really creative because she really likes helping other people do other things and sometimes she gets angry because sometimes she doesn't have the equipment or something, but if she doesn't have the equipment, she gets unmad because she goes to the store and buy new things with her own money.

Interviewer: So what types of things do you do?

Interviewee: We paint, she helped me paint my room, just me and her and she helped me put stickers and paint horses in my room. And she like baked the candle holder for me because I lost my other one and she made a new candle holder for me and she designs like she plants flowers and she puts them in a vase and gives them to me and we paint them. And we paint pots and pans and stuff.

We include this as an example of press because she describes a creative environment, where her sister helps provide the tools and encouragement for her to be creative. Her sister asked her if she wanted to do arts and crafts or design her room, which the girl deemed as things a creative person, such as her sister, would do. She also talked about the tools necessary to be able to do creative work, which are part of the environment, or press. Because we view press as the context within which the person conducts creative processes, and often, products, it can be conceptualized as encompassing of Csikszentmihalyi's (1997) three-part system of domain, field, and person. These parts interact and have different rules for judging something as novel and important, depending on whether one is using big C, pro c, little c or mini c as a framework for creativity. In this example, the girl describes how her press fosters mini or little c creativity. This underscores the value of emphasizing conceptions of creativity beyond big C when working with youth. Providing a social and environmental context that encourages open ended exploration and the chance to be influenced by other's work could be instrumental in this effort.

5. Discussion: Interrelationships between Person, Process, Product and Press

While we found many similarities in how girls described person, process, product and press across art and science, we also discovered two themes that point to differences that girls see in creativity when specifically linked to art or science, and to larger issues about how the girls view art and science as domains. These themes not only show the differences, but also the relationships and interactions between the four Ps.

5.1. Theme 1: Artists and Art Are Inherently Creative, While Science Is Sometimes a Creative Process

We found that the girls often thought that artists and art were inherently creative as people and as a discipline while scientists are creative when engaged in specific practices. When asked whether artists use creativity in their work, many girls described creativity as an inherent dimension of being an artist or of art itself. For example, one girl said, "Creativity is kind of what an artist is. An artist needs to be creative because, like, take the guy who made the melting clocks one, that took a lot of creativity to do the melting clocks, the melting time." In this example, we see creativity being equated with Salvador Dalí's work (1931), or what Kaufman and Beghetto (2009) call big C, "clear-cut, eminent creative contributions" (p. 2). Similar examples included: "you have to pretty much be creative to do different kinds of art", and "drawing and painting are creativity". This view of creativity attributes creativity to the entire enterprise and person because of inherent traits or qualities of the discipline or person.

When asked whether scientists use creativity in their work, many of the girls equated creativity in science to specific practices, such as asking questions, experimenting, or "mixing" substances to together. Examples included:

- They [scientists] have to like first of all, think of what they want to figure out and then create a way to figure it out.
- Sometimes, you just have to go for it. Test things out: be creative on how to test them. And then later, see "Oh, this failed. We should try it this way".

And so, that really helps at the beginning of their science projects.

- Scientists are creative by coming up with theories on how something might work and then trying to figure it out.
- Sometimes scientists can use an invention that's already made and then they can evolve it.

In this view of creative process related to science, creativity is in the practices of science. In the above examples, practices include "test[ing] things out", "coming up with theories", being creative in how scientists "use an invention that's already made" and "evolv[ing] it". This corresponds to Kaufman and Beghetto's (2009) little c level of creativity in that it involves "domain-relevant skills" that "include knowledge, technical skills, and specialized talent" (p. 3). In this view, creative process is tied not to scientists themselves or science as a discipline, but rather to specific practices that they might engage in. This way of thinking about creativity ties to specific scientific practices within the *Next Generation Science Standards* (NGSS Lead States, 2013), such as asking question/designing problems and planning and carrying out investigations.

5.2. Theme 2: Creativity Is Unstructured

Our findings indicate that the girls thought that in art, creativity means that there are no rules, because art is not structured; in science, creativity exists where there is fun and no structure. As more structure or "rules" apply, less creativity is used. The girls saw creativity in art processes stemming partly from their perception of art as having no structure or rules. Examples from this view included:

> I think they [artists] use creativity in their work a lot 'cause there's no rules in art.
>
> It's just fun to just get creative with it [art] and just do whatever you want.
>
> Whoever wants to be creative and wants to just mess around with art, see what they can make, 'cause I just like do random marks until I—like something pops in my head without me even knowing and I just do that.

This view of creativity in art can be linked to the concept of mini c (Kaufman & Beghetto, 2009), in that it reflects an understanding of "personal creativity" (p. 3), or "everyday expressions of creativity" (p. 4) that are involved in personal creation of art. However, it also reflects an understanding of artistic process itself as being non-systematic and without "rules". There is a sense that anything goes in art, and that, related to Theme 1, because art is inherently creative, any processes involved in the creation of art must therefore also be creative. This understanding of creativity and art masks the systematic nature of artistic practice itself and of cognitive practices that occur tacitly in an individual's creative process (Rhodes, 1961). *The National Coalition for Core Arts Standards* (NAEA, 2013) call out the systematic research and preparation that goes into creating a piece of art, as well as practices such as evaluating and interpreting art.

In contrast, the girls' perceptions of science involved more structure and "facts"—and as these increase in the course of a scientific investigation, less creativity is used.

Interviewee: I think [science] is fun and creative in some ways.

Interviewer: Why is it creative?

Interviewee: Science is creative because you start out with your own ideas, you start out with what you think is right. And further into it, you get more serious and you think, "oh, this is wrong. I have to find something else for it". Do research and then you—then it gets less creative. But at the beginning, it's very creative.

Interviewer: Why do you say it gets less creative?

Interviewee: Every project I've done, it gets more serious and—all on the facts... So, if you have science project you're working on and you think, "Oh, this will be a cool idea!" And then you try it. If it doesn't work, you keep trying. It's all based on your ideas. And then, you stick to the facts of what happens. Like, I was doing a project with my class and we were trying to figure out if we should do like, using gravity or things like that for this car thing. And so, we had to find out what worked. And I think that was just more like a creative experience. And then, the more we tried, the more stuck to the facts we were.

In this example, we see a similar view as with art—that scientific processes start out as a "creative experience" when there is less structure and "it's all based on your ideas". As the process proceeds, however, it gets less creative as one gets more "stuck to the facts". This reflects a common understanding of scientific processes as rigid and prescribed (Schwab, 1962), rather than emerging through a creative process.

In fact, there was the sense that because scientists have to do their work accurately, this was in tension with using creativity. Some examples were:

> They [scientists] usually have to kind of accurately—try to accurately figure it out, but they can still use creativity to do something with it, I guess—kind of—maybe not all the time but sometimes, yeah.

Interviewer: Do you think scientists use creativity in their work?

Interviewee: I'm going to go with no because if they're trying to draw something they can't use their creativity because they're science and they have to draw the exact thing otherwise if you're discovering a new species and you sketch if you can't really use creativity.

These examples reflect the understanding that in science, there is a need to convey or discover accurate information and therefore there is no room for creativity. This is similar to a positivist view of science (c.f., Laudan, 1996; Harding, 1991) that argues for a knowable, objective "truth" in the world, and the scientist's job is to discover or represent that truth. In this view, the scientist's own viewpoints, biases, and cultural backgrounds are irrelevant in scientific processes because findings represent objective, universal truths about the world.

More contemporary views of the nature of science (Harding, 1991) argue that scientific processes are a dynamic interaction between scientific expertise, technology, cultural climate, and consensus building within a scientific community.

When taken together, these contrasting views of art (as creative and unstructured) and science (as rigid and less creative) reflect views of the disciplines that do not include more nuanced views of complex practices within each. This represents an opportunity for how a STEAM approach could highlight the overlap in practices between the different STEM disciplines and art, and the role of creativity in each.

6. Implications

Science and art are often viewed as very different from one another, with science representing rationality and logical reasoning while art is seen primarily as aesthetic; thus, creativity is more often associated with art than science (Kind & Kind, 2007). Surveys of student and public perception of science indicate a lack of awareness or appreciation of science as a creative endeavour (Schmidt, 2011). However, there is increasing interest in the overlap between not only art and science, but art and technology, engineering and math, as a way to increase interest, engagement, and learning in STEM.

However, our data suggest that even when art is considered creative in its very nature, seldom were any specific artistic practices described in relation to creativity in art. This begs the question of how we can encourage thinking about creativity within the larger context of art practices. How narrowly or broadly youth conceive of a discipline has implications for how they can identify with that discipline. Conversely, our data suggest implications for the teaching of science as well, given the view that the girls had that while science may start out with creative ideas, the structure involved in scientific investigations lacks creativity. Schmidt (2011) argues:

> A recent review of perspectives and challenges in science education indicates that a belief that there is, and can only ever be, one valid, scientific "way of knowing" is widespread; that the root cause is a lack of alignment between science education/educators and scientific practice. (p. 440)

Coming to understand that creativity can exist in science at different levels of scientific investigation—from applying new measurement techniques to how data are represented—can support an understanding of multiple ways of knowing in science. Supporting students in seeing the overlaps in practices between art and science can be a way to resist "traditional models of teaching and learning have done much to cultivate perceptions of science as a non-creative endeavour" (Schmidt, 2011: p. 411). In fact, Schmidt goes on to argue that "Overt emphasis on rote-learning and rigid, dogmatic adherence to rules of the discipline are not only deterrents for students… they are fundamentally incompatible with the true nature of science" (p. 441).

This suggests, then, that teaching through a STEAM approach, which encourages deep connections between STEM and art disciplines, has the potential to illustrate the creative face of science through highlighting its overlap with art, which is typically seen as creative. In our approach to STEAM education, students engage with scientific ideas—such as the function of color in nature or polarization of light—through the creation of original pieces of art. Our work also holds implications with respect to both domain-specific teaching and transdisciplinary teaching and learning. Schmidt (2011) argues that science education must support creativity by providing opportunities for students to acquire a high level of domain specific knowledge, practice application of knowledge as they develop solutions to problems, and link their knowledge of science to their knowledge of other fields as required to pursue and solve problems of relevance/interest to them. While understanding domain knowledge is important, we emphasize the importance of providing experiences where the overlap in domains, particularly practices, may help engage and interest students in science. This study suggests that more work needs to be done to determine similarities and differences in creativity in art and science and how they can be developed in complementary and intersecting ways to engage students in science. Further work must also be done to investigate how this impacts art- and science-related interest and engagement, as work in STEAM thus far has shown promise and should continue to be investigated.

Acknowledgements

This work was funded by the National Science Foundation (DRL-1224020 and DRL-1223363). Any opinions, findings, and conclusions or recommendations expressed in this article are those of the authors and do not necessarily reflect the view of the National Science Foundation. We would like to thank the instructors and young people who engaged in the Colors of Nature Academy.

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