Journal of Elementary Science Education, Vol. 21, No. 3 (Summer 2009), pp. 63-79.

Creative Activities and Their Influence on Identification in Science: Three Case Studies

Marie-Claire Shanahan, University of Alberta
Martina Nieswandt, Illinois Institute of Technology

The word *creativity* can have a wide variety of meanings and can be applied to products as diverse as a child's drawing or Einstein's theory of general relativity (Mansfield & Busse, 1981). In a general sense, Sternberg and Lubart (1999) define it as "the ability to create work that is both novel (i.e., original, unexpected) and appropriate (i.e., useful, adaptive concerning task constraints)" (p. 3; see also Sternberg, 1988; Sternberg & Lubart, 1991, 1995, 1996). Mansfield and Busse (1981) define creative scientists as "those whose work is considered high in both originality and value by other scientists in the same field" (p. 3).

Despite its central role in science, creativity is a characteristic consistently ignored in popular representations of scientists and their work, especially as they are presented in science classrooms (Braund, 1999). Ignoring creativity and other qualities that are important to the practice of science not only leaves students with a misunderstanding of science, it also limits the qualities and characteristics with which they can identify in the science classroom, which will potentially alienate them from further study. This is of particular concern in students making their first decisions about what science is and whether they see themselves pursuing science in the future (Carlone, 2004; Hughes, 2001). Researchers, such as Koehler, Park, and Kaplan (1999), have argued that the key to bringing new students towards scientific careers and improving their scientific literacy is engaging them during their elementary years.

To address this concern, this study explores three creative activities designed to teach students about Earth and space science and to allow them to explore and express their understanding in imaginative and subjective ways. The goal of these activities was to show students that creativity is an important quality in science with the hope that this would broaden their perceptions of the practice and learning of science and allow a wider variety of students to build a science identity.

Theoretical Framework

Creativity in the Practice of Science

Several descriptions of creative innovation can be found in historical accounts of science (Berson, 1999; Lambert, 2002; MacCormac, 1976; Sternberg, Kaufman, & Pretz, 2002). Creative strategies, such as analogy building, are important vehicles for reorganizing thoughts and seeing things in new ways. MacCormac (1976) highlights the immense power of these strategies to help make strange and unimaginable concepts more accessible, suggesting that "only through some such device as metaphor is it possible to develop new meanings in new theories that are intelligible. Metaphors have a hypothetical nature; they suggest possible meanings to us" (p. 36).

Psychologists of science also recognize that rationalist accounts of scientific investigation are insufficient and inappropriate to describe the work of recognized creative scientists (Mansfield & Busse, 1981). Many researchers focus their attention on the individuals involved in scientific discovery and on the creative intellectual and dispositional qualities they possess. This research explores the ability that these individuals have to generate remote associations, divergent thinking, and creative images (Mansfield & Busse, 1981; Rothenberg, 1987; Simonton, 2003).

Prominent scientists themselves have also recognized that they are involved in an essentially creative endeavour. Max Plank (cited in Simonton, 2003) went as far as to claim that successful scientists "must have vivid intuitive imagination, for new ideas are not generated by deduction, but by an artistically creative imagination" (p. 475).

Creativity in the Science Classroom

The importance of creativity to historians, psychologists, and practicing scientists begs the question, "How is it being fostered in and presented to students of science?" The unfortunate answer is that, for the most part, it is not. Within the goals of many science curricula are so-called scientific attributes, but these attributes most often focus only on the rational-empirical aspects of science. For example, the *Benchmarks for Science Literacy* (American Association for the Advancement of Science [AAAS], 1993) hints at the importance of creativity by including imagination and inventiveness in a description of scientific "habits of mind," but the focus is clearly on the more conventional skills (including quantitative analysis and critical thinking skills) and attitudes (such as scepticism and curiosity). Creativity does not appear in any of the specific expectations for the elementary grades. The *National Science Education Standards* (National Research Council [NRC], 1996) are no different. They allude to the general importance of creativity to the practice of science but offer no specific expectations for its development.

If we are attempting to prepare students to understand and use science either as professionals or as informed, responsible citizens, then it seems very surprising that something deemed essential to both professionals in science and to the development of the discipline itself is not more thoroughly addressed in science education. Science students need to know that scientists are creative individuals who use their imagination to discuss, explain, and hypothesize in science.

Creativity and Identity in Science

A further concern about the exclusion of creativity from school science is that, when it is missing, students are offered a narrow view of what it means to be someone who does science. Students' perceptions of science have consequences for the connections they are able to make to the discipline and the degree to which they are able to see themselves as individuals who belong in science and are capable of doing science (Barton, 1998; Brickhouse, Lowery, & Shultz, 2000; Brickhouse & Potter, 2001; Lee, 1998, 2002). In other words, students' perceptions influence the degree to which they are able to develop identities as science students. This is of particular concern in the elementary classroom where students make their first decisions about the subjects they enjoy and wish to continue to study in later years.

Barton (1998) defines school science identities as "who we think we must be to engage in science" (p. 379). In science classes, students are presented both explicitly and implicitly with the qualities and interests commonly considered to be most desirable in a science student. Unfortunately, the dominant identity presented to students in the classroom is strongly tied to the conventional scientific attributes or habits of mind discussed above (Carlone, 2004). This reinforces to students a particular vision of who students need to be to engage in science and ignores a wide variety of qualities and abilities important to the practice and learning of science.

Rationale and Research Questions

This study, therefore, explores creative activities as a way of bridging the gap between students and science by broadening the qualities that students perceive to be important in the science classroom. Creative activities, such as those designed for this study, present a subjective way of accessing science concepts, which could allow students with more creativity- and subjectivity-oriented self-perceptions to narrow the gap between themselves and science.

With these objectives in mind, the following questions have guided the cases presented here: (1) Will creative activities influence the students' perceptions of the expectations placed on them in the science classroom? and (2) How will a shift in these perceptions influence any discrepancy that students experience between themselves and the expectations of the science classroom?

Methods

This study explores three students' reactions to creative activities. The three students profiled were part of a larger mixed-method study involving two Grade 6 classes: one at a single-sex girls' school and one at a single-sex boys' school. The students were selected on the basis of their answers to two subscales on a questionnaire administered a week before the creative activities began. These subscales addressed self-identification with creativity and with science.

The students were chosen to represent three possible combinations of identification: (1) strong identification with creativity and weak identification with science (Alison), (2) strong identification with science and weak identification with creativity (Sarah), and (3) weak identification with both of these domains (Bryan). For the purpose of this selection, strong and weak identification were defined as having a maximum or minimum score on the subscale of interest. It is noteworthy that no students identified strongly with both science and creativity.

School and Classroom Context

Both schools are located in a large city in Southern Ontario and are attended primarily by children of professional parents of European, Asian, and South Asian backgrounds. The schools have strong academic programs and both require an entrance exam. The students are, in general, high achievers. Class sizes at both schools (girls' school: 24; boys' school: 21) are below the provincial average.

Creative Activities

Three activities were designed to highlight different forms of creativity: (1) painting/drawing, (2) engineering design, and (3) dramatic presentation. These activities covered specific curriculum expectations from the Grade 6 Earth and Space Sciences strand. Both teachers decided to use the activities as their first three lessons in the Earth and Space Sciences unit (the fourth of five science units to be taught that year). Each activity was confined to one class period (approximately 80 minutes) and taught by the regular classroom teacher.

In the first activity, *painting and drawing*, the teachers introduced their students to photographs of interstellar nebulae, and through a guided discussion, they explored scientific explanations of characteristics such as shape, colour, and origin. Each student then created a unique nebula using paints, pastels, and crayons and wrote a paragraph describing the history, shape, and composition of their nebula.

The second activity, *engineering design*, challenged students to build a model of a landing vehicle that could be used to land on a particular planet in our solar system. Students were first asked to suggest considerations, such as gravity, surface material, and temperature, that would be important to consider in the design of a landing vehicle. They were then provided with books and Internet resources and given approximately 20 to 30 minutes to research the important characteristics of their assigned planets. Using this information and a variety of recycled and new materials (e.g., balloons, yoghurt containers, cotton balls, popsicle sticks), students worked in pairs to create model landing vehicles with features that could withstand the conditions on their particular planet. For homework, the students wrote individual paragraphs describing their vehicles and how they met the challenges presented by the planet.

In the third activity, *dramatic presentation,* after a lesson on the relative positions of the Earth, moon, and sun and how these positions create the phases of the moon that we see from Earth, students worked in groups of four or five to create presentations demonstrating or explaining the phases of the moon and lunar and solar eclipses using drama, dance, mime, or tableau. Students were encouraged to consider creative and original ways of demonstrating their understanding rather than simple movement models of the sun, moon, and Earth system.

In all three activities, students were required to understand canonical scientific knowledge (e.g., relative positions of the Earth, moon, and sun or the relationship between gas composition and apparent colour in a nebula) and use creativity to present this understanding in a novel and appropriate way, consistent with Sternberg and Lubart's (1999) definition of creativity. Representing scientific concepts accurately was an important aspect of these activities. They were repeatedly probed and encouraged to explain and illustrate the connection between their work and their scientific understanding. This is analogous to scientists whose creativity is exhibited in the restructuring and rethinking of established bodies of knowledge.

In addition, each activity was accompanied by a writing assignment that allowed the teacher to assess the students' development of content knowledge. It should be noted, however, that while scientific content was an important aspect of these activities, we did not have access to the teachers' assessments of the students' work.

Data Collection

The three student cases presented here were created from data collected through classroom observations, interviews, and written responses to the activities. All data collection was aimed at understanding the students' experiences during the activities and the connection between these experiences and their identification in science. Assessment of their content learning or the relationship between content learning and identity was not the central focus of the study.

The observations were conducted during each of the three activities and during one regular science class prior to the start of the activities (a total of five hours of observations in each class). The data were recorded in the form of field notes chronicling the actions and words of the selected students. Direct quotes were recorded whenever possible (see Table 1 for the "Observation Guide").

Table 1. Observation Guide for Classroom Observations of Case Study Students

Areas of Interest and Guiding Observation Questions
• Interactions with other students (e.g., Are the students leaders in the class or more passive participants? Do they express their ideas to other students? Do they accept ideas expressed by other students?)
• Interactions with the teacher (e.g., Do they ask for help or clarification? How do they respond to encouragement or criticism from the teacher?)
• Class contributions (e.g., Do they express opinions during the class? Do they answer factual or recall questions? Do they attempt to analyze information or bring in information from other areas?)
• Use of creativity (e.g., Do they readily attempt to create representations of their understanding? Do they relate information to novel situations? Do they attempt only to use ideas that were presented in class or already used by other students?)
• Triangulation with interviews (e.g., Do they act in ways that support their descriptions of themselves?)

The students were also interviewed individually before and after participation in all three activities (one week prior to the first activity and one week following the final activity). This resulted in a total of one hour of interviews per student. The interviews were semistructured. A group of core questions was asked of all three students (see Table 2), and individualized questions were created based on the students' answers to the questionnaire items and their in-class actions and contributions (e.g., "I noticed during class that your group members often asked you for help. How do you feel about being asked to help your classmates?"). These interviews were tape recorded and transcribed verbatim.

Additionally, the students' answers to two written open-ended questions were collected in class immediately following the completion of the third activity: (1) Please describe your experiences participating in these lessons, and (2) If science classes included more activities like these, how would your opinion of the qualities needed by a good science student change?

Table 2. Planned Questions Asked to All Students in Pre-Activity and Post-Activity Interviews

Pre-Activity Interview	Post-Activity Interview
• What do you think it means to be a good science student? • What qualities do good science students have? • Is being a good science student different than being a good student in general? • Would you say you are a good example of a science student? Why or why not? • What are some things that you enjoy about science class? • What are some things that you do not enjoy about science class? • How does your personality affect the way you feel about science class? • How do your friends influence the way you feel about science class? • How do your parents and family influence the way you feel about science class?	• How did you feel while participating in the three space lessons? • Describe which one you enjoyed the most. • Describe which one you enjoyed the least. • Were there any parts of your personality that you felt were useful for these activities that are not usually important in science class? • How would you compare your enjoyment of these lessons to your usual enjoyment of science class? • Would your opinion of yourself as a science student change if more lessons were taught this way? • How did these lessons influence the qualities that you feel are important for a science student?

Data Analysis

The analysis began by dividing the text of the transcripts and field notes into short, related sections ranging in length from a phrase to several sentences. The sections were organized into four categories: (1) aspects of students' personal identities, (2) their relationship to and identification in science, (3) their experiences during the activities, and (4) possible changes in their identification with science. These categories were created (1) based on the way in which identity has been approached in the literature and (2) to address the specific goals of this study. In keeping with studies such as Brickhouse et al. (2000) and Brickhouse and Potter (2001), which highlight the relationship between personal and science identities, we wanted to gather separately those data points related to students' personal identities (e.g., their out of school interests; their self-perceptions as shy, friendly, creative, etc.) and those related to their identification in science (e.g., interest in science, desire to study science, wanting to be recognized as a "science person"). This decision created the first two categories. The final two were created *a priori* to address the goals of this study (i.e., what were the students' experiences and how did these experiences impact their identification in science).

Once sorted into these categories, the segments of text were descriptively coded. Each segment was assigned a code to describe and summarize the meaning of the segment. For example, "I like designing. Like making the nebula, I just kind of like got to express myself and show my creativity" was coded as "show my creativity." All of the coding decisions were discussed by both researchers until an agreement was reached.

From these codes, we created a preliminary case description for each student by bringing similar codes together under larger pattern codes (e.g., "strong science student identity"). The written responses to the open-ended questions were then analyzed for evidence supporting or refuting the preliminary case descriptions. New codes emerging from the observations, and written responses were added to the case descriptions. It should be noted that although we were open to contradictory evidence, there were no situations in which major discrepancies were found between the data sources (e.g., no instances in which students described themselves in one way but acted a different way during class).

Results

The results of the analysis of interviews, written response questions, and classroom observations will be presented here in the form of three individual case descriptions.

Alison

Alison was enthusiastic about being interviewed for this study and presented herself as a confident, articulate, and friendly person. She described herself as artistic and creative and was proud to have won the Junior School Art Prize at a recent school awards ceremony. Her abilities to paint and draw were central to her description of herself as creative: "I always draw, and I always do artsy things sort of. In art, I always paint and do a lot of things" (pre-interview). In classroom observations, we noted that she had several small paintings and sketches taped to her desk and a well-used sketch pad in the storage space under her desk. She also felt that others viewed her as creative, saying, "I've just been told I have a really creative mind, and I've been told that I'm really, really creative" (pre-interview).

When it came to science, she described good science students predominantly in terms of their behaviour in science class. Her perceptions reflected aspects of a conventional understanding of good science students: those who want to be scientists when they grow up, those who behave well in class, and those who can understand the "hard" concepts in science:

> I just think a good example of a good science student is they're always organized and they always, they're always ready for things. . . . They also think about doing really, really well in science and becoming a famous scientist, because a girl in our class, her dad is like a scientist and she really, really wants to be a scientist when she grows up. And she would make a perfect scientist. She's really smart, and she's really patient and nice and happy. In class it's just like she always listens. She's always prepared. She's always listening. She's just an example of a perfect science student. (pre-interview)

Her descriptions also represent a common understanding, or misunderstanding, of what female science students should be: studious, intelligent, hard working, and quiet (Hughes, 2001). A picture she drew of a good science student reinforced this understanding. She drew a girl at her desk, hunched over her work and said that the girl was working on a worksheet: "doing her work and listening" (pre-interview).

Although Alison was quite certain about what a science student should be, she was not sure how well she met these expectations. She felt that her own behaviour sometimes made her a good science student but that often she got distracted and missed out on parts of the discussion. She said that she usually talked to her classmates too much and liked to draw during class:

> The part of me that I don't think is [a good science student] . . . is sometimes I get a little distracted. Sometimes I draw something on my sheet of paper. Sometimes, I lose track of time and I completely stop listening for a little second and when I go back to listening, she's talking about something else and I'm like "Oh no!" Sometimes I don't listen completely. (pre-interview)

During the observation of the pre-activity class, Alison was observed engaging frequently in chatting with classmates. On that day, students had the opportunity to move around the room to see and test electrical games that their classmates had designed. Alison quickly became distracted by the opportunity to socialize. She moved jovially around the room, laughing and talking to classmates about topics other than science and the task at hand.

Alison identified much more as an art student. In art, she felt that she could answer other people's questions and help them; whereas in science, she was usually the one who needed help. During our observation of a regular science class, we observed Alison asking questions of other students frequently (e.g., "What did she [the teacher] mean about this?"). She also appeared uncomfortable answering questions from other students. On one occasion during this class, a classmate asked her for assistance, and she responded, "Oh, I have no idea. You should ask Carol [another student]. She'll probably know" (observation).

During the creative activities, however, her social and artistic skills/abilities seemed to be an advantage—an advantage that overcame her usual reticence and distraction. She expressed a high degree of comfort and enjoyment during the activities, higher than in a usual science class:

> I thought, because I know for a fact that I'm really creative, everyone tells me that I'm creative, I just thought that when we were designing the landing machines and drawing the nebula, I just thought that I could express myself. (post-interview)

> I like designing. Like making the nebula, I just kind of like got to express myself and show my creativity. (post-interview)

In addition, during the landing vehicle activity, her ability to get along with people and cooperate was evident. During the activity, she was observed to be laughing and working enthusiastically with her partner. She also seemed to work to validate her partner's ideas and encouraged her partner to contribute even though her partner was a quieter student. She made statements such as "Ya, Alisa, your idea is great!" and "Hmmm . . . I'm not sure if what I said will work. What do you think?" (observation).

From the observations, it was also evident that she was well-engaged with the science content of the vehicle activity and made strong connections to the research they had conducted about the planet. For example, when the teacher asked her to describe the vehicle, Alison said "Now, because the gravity on our planet is so strong—much stronger than on Earth—I think we need to be extra careful how our machine lands" (observation).

She was also observed to be more engaged in on-task talk during these activities than in the regular class that we observed. During both activities, all of her interactions with students and the teacher were related to the tasks. She asked deeper questions that illustrated thoughtful consideration of the topic (e.g., In reference to colour pictures of two nebulae, "I understand why the colours will be different for each of the nebulas, but what I still don't understand is the shape. Why is this one more of like kind of an oval and this one is more a circle?" [observation]). This contrasts with the questions that she asked during the previous class. These were primarily factual questions asked because she had missed what the teacher had said or she did not understand a term that was being used.

In the final interview, Alison expressed very positive experiences with these two activities (she was absent for the moon phases drama). Since she felt confident in her creative and cooperative abilities, these activities made her feel like she could be a good science student. While participating in them, she said that she felt, "ready to do anything. I just [was] feeling secure and good about myself" (post-interview). It was clear from her interactions with students and the teacher that her strengths were valued and that the classroom expectations during the activities matched with Alison's creative and cooperative strengths. In the words of identity research, her self-perceptions matched the science student expectations during these activities. Research suggests that this match can also lead to positive emotions such as enjoyment, interest, and satisfaction (Burke, 1991)—all of which are evident in Alison's comments. Furthermore, Alison felt that more activities like this would make it easier for people like her to learn:

> It was easy to understand and there was a lot of information, so I would think that a person who wasn't very good at science would understand it and feel good about—feel that she could do it. (post-interview)

Her final comment on the written response summed up how the activities affected her learning in science: "Overall, these activities were very fun. It boosted my confidence and I will never forget them" (written response).

Alison is an example of a student who was able to participate more fully and confidently in science through the inclusion of creative activities. As expressed in her interviews and written response, they reinforced her identification with creative and cooperative pursuits while also allowing her to explore and perhaps strengthen her scientific identification by bringing her strengths into the scientific domain.

Sarah

Sarah is a calm, careful, and articulate student who seemed to take the interview process very seriously. Her answers were clear, concise, and well-considered. This outward presentation was very much in line with the description that she gave of herself as someone who was very concerned with doing the right thing and who cared very deeply for those around her. Her concern for others seemed very central to her identity and came up numerous times during the pre-interview. For example:

> I think I care a lot about people because I always want to do things that make other people feel better, not so much myself, more what will make other people happy and so I listen to what they say and I watch them. (pre-interview)

She also felt that her concern with doing the right thing and following the rules made her different from a lot of the other girls in her class:

> A lot of people my age I think feel like they don't have to follow the rules; they just have to sort of be unobediant and sort of talk and talk and never do work. I've never really felt comfortable doing that. I always follow the rules and do what I'm supposed to do. (pre-interview)

This self-perception also matched with her description of a good science student: "I think they should ask lots of questions if they don't understand things and listen to their teacher" (pre-interview). Sarah felt that this type of behaviour was part of what made her a good science student: "Generally, I pay attention in class and I work hard, and I ask questions if I don't understand things" (pre-interview). In contrast to Alison, she did not feel that asking questions made her a weak science student—she felt it was part of what made her strong. In the pre-activity class, however, the types of questions that she asked appeared different than Alison's. Instead of asking for clarification of terms or ideas that she had missed, she asked how ideas were related and how concepts might apply in new situations (e.g., "So is this the same kind of circuit that we used last time with the Christmas lights? It looks like it works the same way" [observation]). She was also a frequent contributor, offering both factual answers (e.g., the terms *series circuit* and *parallel circuit*) and self-generated explanations (e.g., "I think because they have hooked up the bulbs differently, there is different current in each one" [observation]).

Her father, who is a scientist, has also nurtured her interest in science. She says that he "thinks about science the same way I do" (pre-interview). She described this as a mathematical way of thinking:

> Generally, I think about stuff in a mathematical way. Sometimes people will be talking about a completely different subject, and I'll figure out the math part of it. Like [our teacher] was talking about how many people were going to be admitted to the school, and I was figuring out all these numbers in my head to figure out how many people weren't and all that kind of stuff. (pre-interview)

Taken together, this evidence suggests strong identification in science. She self-identified as a strong science student, and science was an important aspect of her personal identity. Her self-perceptions as an interested and diligent science student were also supported by her classmates. For example, when Alison described a classmate who was an excellent science student, it was Sarah who she was describing:

> A girl in our class, her dad is like a scientist and she really, really wants to be a scientist when she grows up. And she would make a perfect scientist. She's really smart and . . . . In class it's just like she always listens. She's always prepared. She's always listening. She's just an example of a perfect science student. (Alison, pre-interview)

Although she exhibited strong identification in science, Sarah noted that she was not a perfect match for the ideal characteristics of a science student:

> I think I sometimes have my mind too set on one way of thinking that I don't have an open mind. I think I listen well enough, and I look around enough, but I think I have to sort of think other ways sometimes. (pre-interview)

She generalized this self-perception by saying that she was not generally very creative either. She felt that she had some creative ideas but had difficulty bringing her ideas to fruition. She felt she was more comfortable when tasks were analytic rather than creative.

During the three activities, her scientific identification continued to be prominent. During the introductions to both the nebula and moon phases activities, she raised her hand several times to make connections between the material that was being introduced and previous topics from other units and other grades. On one occasion, she said, "Remember that space movie we watched in Grade 3. I think this is what they were talking about" (observation). This comment was followed by several nods of agreement from her classmates. During the nebula activity, she engaged her fellow students in discussing the scientific content of the lessons. She asked other students, "Oh, I like the colour you used, what type of gas would that be?" and "From the shape, yours is an emission nebula, right?" We also observed that she spent most of the class time writing a factually detailed description of her nebula. She carefully included the new terms that had been introduced, checking with a classmate to see if she felt the description matched well with the painting.

During the landing vehicle activity, Sarah's scientific identification was particularly prominent. She was enthusiastic about all aspects of the activity, including both the research and building portions. Her time was not disproportionally divided as it had been in the nebula activity. She worked diligently with her partner and was observed being careful to connect each aspect of her design to the conditions on her planet. In designing, she steered her partner towards suggesting design solutions specifically related to the constraints of their assigned planet. She was heard to say to her partner, "We need to do this right if we're going to be scientists. They would make sure that every detail was done for a reason" (observation). She expressed that this activity allowed her to best use her scientific strengths:

> I really liked the landing vehicle thing because it was a really fun way to combine learning about a planet with doing something fun, and I really liked getting to work with a partner and finding out about another planet. (post-interview)

Despite her success in the first two activities, the moon phases activity proved to be more challenging; she found it difficult and frustrating because of its relationship to her self-perceptions of creativity. She was very quiet in her group during the planning and took only a small, nonspeaking role in the presentation—contrasting starkly with her active engagement in the other two. During the presentation, she held up signs made of construction paper with the words "solar eclipse," "lunar eclipse," "full moon," etc. She maintained a serious and concerned expression on her face during the entire presentation and walked away at the end while her group members bowed and accepted applause from the class. She was explicit in expressing her lack of comfort during this activity:

> In the drama one, I didn't exactly feel that I could do it well because I'm not very dramatic. (post-interview)

> I'm not really a dramatic person, but I think most people liked the drama one. I think I'm sort of one of the only people that didn't like it, so I think it was just sort of a personal thing. (post-interview)

In talking about this activity, she also made no mention of the science content despite having expressed, in the first interview, a personal interest in the moon and the Earth-moon system. She also did not engage in discussing the content with her group members and offered only one- or two-word answers primarily in the form of terminology (e.g., she corrected a classmate who used the terms *solar* and *lunar* incorrectly).

The key question to ask of Sarah's participation is whether the activities, especially the moon phases drama, impacted her strong scientific identification. Her written responses and comments during the post-activity interview suggest that it did not. She appeared to focus on how the first two activities allowed her to showcase her scientific knowledge and skill in different ways, and in reference to the third activity, she made attributions solely to her creative skill. She felt that her impressions of science would remain the same even if it included more activities like this:

> I think it would have changed a bit because it seemed, it would seem that you have to be more creative for it, but I think if we got more used to them, the perception would go back to how it is, that it's pretty much the same stuff but just a different way of sort of putting it together. For example, we might answer a question in the textbook like "If you were to create a nebula what would it look like?" . . . We did the exact same thing. (post-interview)

When asked to expand this idea to the drama activity, however, she just responded that she would do badly in the drama activities because she is not dramatic but that it wouldn't change what she thought about science.

The analysis demonstrates that Sarah's identity as a science student remained solidly intact during these activities, while the weakness of her creative identification was heightened. Sarah seems to have already incorporated a science student identity that does not include this type of creativity. She also felt that in all of the activities, it was the scientific content that mattered and not the way that it was expressed.

Bryan

Bryan approached the interviews very earnestly. He considered his responses carefully and seemed to want to be very honest in judging his character and abilities. He considered himself a hard worker, which was evident from his diligent work during all three activities. He took great care in all the work that he did. For example, during the nebula activity, he was one of the only students to complete a detailed sketch of his nebula before he began painting. But when asked to describe qualities that he wished he had, he said, "An ability not to give up as easy. Sometimes when I don't get things, I get frustrated. If I just keep going and find a way just to figure it out, that would help me" (pre-interview).

Science was also particularly difficult for him when he could not figure out the "right answers":

> Sometimes, when I'm working on [science work] and I get frustrated and then I just get rid of it because I just can't work it. But when I actually get it to work, then I'm a good [science student], but when I don't get it to work, I get kind of frustrated and do bad stuff with it or throw it. (pre-interview)

We did not observe any direct evidence of this frustration during the pre-activity class, but he told us two stories in which he became frustrated with scientific projects and ended up ripping up the papers and destroying the materials with which he was working (e.g., "I had this weird car . . . that you had to attach batteries, and I could never get it to work, so I just threw it down the stairs" [pre-interview]).

With the creative activities, on the other hand, he felt that there were many ways to get it right and that he did not need to be as frustrated. With the nebula, he just started with something and then could take it anywhere he wanted and have a positive, successful product. For example, while painting, he accidentally wiped a watery brush across his paper and smeared the paint. He frowned for a moment and then smiled and said to the student beside him, "Hey, mine looks like an emission one now; I'm going to change it" (observation). He explicitly noted the freedom that this activity offered for changing directions:

> I really liked building the nebula, like creating the nebula. Like what happened was I just started drawing and then it just turned out one way and then I just added some other things to make it look the same. . . . I just drew one idea and then saw what it looked like and drew it from that. (post-interview)

> You just could be creative in all of them, but [the nebula] was the most creative because you could add what you wanted. You got to start from scratch. You just went and started it your own way. (post-interview)

He also enjoyed creating the landing vehicle for the same reason. There was no right way to do it. You could take your information and do what you wanted with it:

> Like for your lunar lander, you could create the body the way you wanted it. All you needed to know was like the temperature so you could figure out if it was warm. You just needed to know some basic things about it and create it so it was pretty much the way you wanted it. You got what you wanted. (post-interview)

He was actively engaged with his partner throughout the activity. He seemed more drawn, however, to the design aspects rather than the science content aspects. Though they worked together, Bryan's partner primarily consulted their research notes, and Bryan primarily responded with design ideas for the lander. For example, his partner read, "Okay, so our planet is Venus and it has really thick clouds. It's going to be hard for someone to look out the window to steer," and Bryan responded, "Hmmm . . . it will need to have lots of computer sensors, but maybe we should make sure that the wings aren't too long either, so there is less of a chance of running into something" (observation).

During the moon phases activity, he acted as a leader in his group, but he did not approach it with a strong pre-existing plan. He was willing throughout to entertain new ideas and new directions. The group started to act out possible ideas, and as things came up, he said "That's a great idea. Why don't we do it that way!" and "Oh cool, I didn't think of that. What if we changed it so that our moon was over here?" (observation). He really appeared to enjoy the openness of the task and being able to take it in different directions as different ideas emerged. His earlier comments suggest that he enjoyed this aspect of all three activities.

If science class included more activities like these, he said that he would be able to enjoy it more. He said, "I'd feel more comfortable because I could be creative" (post-interview). His final comment in his written response also expressed his higher comfort level with creative activities because there is not just one single answer that he has to find: "I think if science class had more activities like this, you wouldn't have to be as smart, and every answer [would] mostly be the right answer" (written response).

For Bryan, using creative activities was a chance to participate in science without getting frustrated if he did not find the "right answer." He could use his creativity and find his own answer. It was a way for him to feel that he could meet the expectations of the science classroom and potentially move towards developing a stronger identification with science. He did not address this identification directly, but, like Alison, his comments suggest that during these activities, he was able to make a better match between his abilities and the expectations. For Alison, this was accomplished by bringing her strengths into science activities, but for Bryan it was more about creating situations in science where he could relax and start exploring science without giving up when he could not find the right way to do things. It is not always possible or desirable to have "every answer mostly be the right answer" in a science classroom, but in many cases, there are several ways to understand or conceptualize a topic or to solve a problem, and for Bryan, the opportunity to learn science in this way was liberating.

Discussion

These three case studies provide some key examples of the types of responses students may have to creative activities. For Alison, it was an extremely positive experience and one that was coherent with her self-perception as being creative. She found that by using her creative and artistic abilities in science, she was able to meet the expectations of the science classroom. Bryan also had a very positive reaction to the activities. While he was easily frustrated in regular science classes when he was unable to find the expected answer, the creative activities allowed him to experiment and follow different paths until he was satisfied with an answer or a certain product. Sarah's reaction was very different. She began the activities with a strong science student identification and a self-perception of lacking creativity. This was reflected in her reaction to the different activities. The only activity in which she felt truly comfortable was the lander design activity because of its more concrete connection to her science identity.

In discussing the possible benefits of integrating creative activities into the elementary science classroom, it was argued that they present a more subjective way of accessing science concepts and could allow students with more creativity- and subjectivity-oriented identities to narrow the gap between themselves and science. The case studies of both Alison and Bryan suggest that this is possible. They both expressed a change in their understanding of the expectations of science (as more creative or more open-ended) and a subsequent feeling of being a better science student.

Sarah's experiences were different although not necessarily negative. The first two activities supported and affirmed her scientific identification and provided ways for her to engage deeply in the content in new ways. The third activity did not affect her already strong interest and identification in science but led to some discomfort due to her self-perceived artistic and dramatic weaknesses. The emotional state of discomfort could be a starting point to a further broadening of her current science identity, however. It would have been interesting to follow Sarah's participation in creative activities further to explore whether they could be used to help her develop her creative thinking skills and come to recognize creativity as important to the practice of science.

It is important to note that, on the surface, these activities may just seem like fun interludes that gave students an enjoyable break from their regular science classes. The students' responses suggest that the activities were fun, but looking deeper into their reactions suggests potential shifts in their identification with science. Both Alison and Bryan expressed noticeable decreases in the discrepancy between their self-perceptions and the expectations of the science classroom during these activities. Both students were able to articulate this change and the positive effect that it had on their experiences. This decrease in discrepancy may have precipitated positive emotions such as enjoyment and interest for both students. This supports the assertions of identity researchers such as Stryker and Burke (2000) and science education researchers such as Barton (1998) and others (e.g., Brickhouse et al., 2000; Brickhouse & Potter, 2001; Lee, 1998, 2002) who have argued that to increase student interest and participation in science, teachers must find ways to bridge the gap between students' perceptions of themselves and the way they perceive scientists and successful science students.

In making statements about the potential impact of these activities on students' identification, we recognize that this is a preliminary study based on only three activities. It is difficult to definitively attribute students' reactions to the creative nature of the activities. Further research would be necessary to explore the possibility that the inclusion of any novel activity would have had similar results. We feel that the results suggest a connection to the creative aspects, especially in the cases of Alison and Bryan, but recognize that this cannot be claimed conclusively at this time.

The other reason for advocating the inclusion of creative activities is their potential to challenge the idea that creativity is unscientific and to help students realize that it is an important part of the scientific process. At the conclusion of this short study, two of the three students (Alison and Bryan) stated that if science included more activities like these, they would see creativity as an important quality in the science classroom. Further research is necessary to determine whether students would extend this to their understanding of science in general. It would also be important to probe their exact understanding of creativity. Can they build bridges between thinking creatively to produce the products required in these activities and the novel thinking and representation that are necessary in the practice of science?

In summary, the results of this study support the integration of creative activities into the science classroom for two interrelated reasons. First, creativity is an important attribute in the scientific community and, if we want to give more elementary students a realistic understanding of science, it should have a place in the science classroom. Second, activities that encourage creativity and subjective expressions of scientific understanding, such as those designed for this study, have the potential to decrease the discrepancy that students may perceive between the expected habits of mind of the science classroom and their self-perceptions—a decrease that may encourage identification in science and lead to more students developing and maintaining an interest in science.

References

American Association for the Advancement of Science (AAAS). (1993). *Benchmarks for science literacy: Project 2061*. New York: Oxford University Press.

Barton, A. C. (1998). Teaching science with homeless children: Pedagogy, representation, and identity. *Journal of Research in Science Teaching*, *35*, 379-394.

Berson, J. A. (1999). *Chemical creativity: Ideas for the work of Woodward, Huckel, Meerwein, and others*. Weinheim, Germany: Wiley-VCH.

Braund, M. (1999). Electric drama to improve understanding in science. *School Science Review*, *81*, 35-41.

Brickhouse, N. W., Lowery, P., & Schultz, K. (2000). What kind of a girl does science? The construction of school science identities. *Journal of Research in Science Teaching*, *37*, 441-458.

Brickhouse, N. W., & Potter, J. T. (2001). Young women's scientific identity formation in an urban context. *Journal of Research in Science Teaching*, *38*, 965-980.

Burke, P. J. (1991). Identity processes and social stress. *American Sociological Review, 56,* 836-849.

Carlone, H. B. (2004). The cultural production of science in reform-based physics: Girls' access, participation, and resistance. *Journal of Research in Science Teaching, 41,* 392-414.

Hughes, G. (2001). Exploring the availability of student scientist identities within curriculum discourse: An anti-essentialist approach to gender-inclusive science. *Gender and Education*, *13*, 275-290.

Koehler, B. G., Park, L. Y., & Kaplan, L. J. (1999). Science for kids outreach programs: College students teaching science to elementary school students and their parents. *Journal of Chemical Education, 76,* 1505-1509.

Lambert, L. B. (2002). *Imagining the unimaginable: The poetics of early modern astronomy*. Amsterdam: Rodopi.

Lee, J. D. (1998). Which kids can "become" scientists? Effects of gender, self-concepts, and perceptions of scientists. *Social Psychology Quarterly*, *61*, 199-219.

Lee, J. D. (2002). More than ability: Gender and personal relationships influence science and technology involvement. *Sociology of Education*, *74*, 349-374.

MacCormac, E. (1976). *Metaphor and myth in science and religion*. Durham, NC: Duke University Press.

Mansfield, S. M., & Busse, T. V. (1981). *The psychology of creativity and discovery: Scientists and their work*. Chicago: Nelson-Hall.

National Research Council (NRC). (1996). *National science education standards*. Washington, DC: National Academy Press.

Rothenberg, A. (1987). Einstein, Bohr, and creative thinking in science. *History of Science*, *25*, 147-166.

Simonton, D. K. (2003). Scientific creativity as constrained stochastic behavior: The integration of product, person, and process perspectives. *Psychological Bulletin*, *129*, 474-494.

Sternberg, R. J. (1988). *The nature of creativity: Contemporary psychological perspectives*. Cambridge, UK: Cambridge University Press.

Sternberg, R. J., Kaufman, J. C., & Pretz, J. E. (2002). *The creativity conundrum: A propulsion model of kinds of creative contributions*. New York: Psychology Press.

Sternberg, R. J., & Lubart, T. I. (1991). An investment theory of creativity and its development. *Human Development*, *34*, 1-32.

Sternberg, R. J., & Lubart, T. I. (1995). *Defying the crowd: Cultivating creativity in a culture of conformity*. New York: Free Press.

Sternberg, R. J., & Lubart, T. I. (1996). Investing in creativity. *American Psychologist*, *51*, 677-688.
Sternberg, R. J., & Lubart, T. I. (1999). The concept of creativity: Prospects and paradigms. In R. J. Sternberg (Ed.), *Handbook of creativity* (pp. 3-15). Cambridge, UK: Cambridge University Press.
Stryker, S., & Burke, P. J. (2000). The past, present, and future of identity theory. *Social Psychology Quarterly*, *63*, 284-297.

Correspondence regarding this article should be directed to

Marie-Claire Shanahan, Ph.D.
Assistant Professor
Elementary Science Education
University of Alberta
551 Education South
Edmonton, Alberta, Canada, T6G 2G5
(780) 492-0870
Fax: (780) 492-7622
mcshanahan@ualberta.ca

Manuscript accepted October 2, 2008.