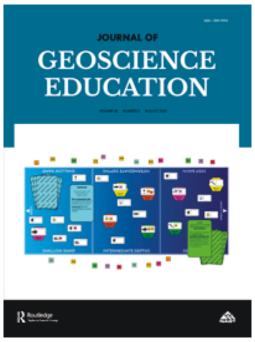

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How various material resources facilitate science identity work for girls in a research apprenticeship program

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ABSTRACT

Situated learning experiences such as research apprenticeships can help connect girls to the sciences, ultimately helping to achieve gender equity in the science workforce. The material resources available in research apprenticeships—such as research equipment, field gear, etc.—may be particularly consequential for building identification with science, as they are abundant and frequently hold disciplinary authenticity. However, most sociocultural studies of research apprenticeships have focused on cognitive-ideational or social aspects rather than on the material aspects of the learning setting. This paper investigates the association between different types of science-related material resources in the context of a geoscience and biology-focused research apprenticeship program for girls. The study employed a qualitative approach, drawing on theoretical constructs of communities of practice, identity resources, and identity work to inform program design and analysis. Our findings highlight specific ways that instruments, specialized clothing, specimens, artifacts, and physical settings of science intersect with science-related affect, science learning, and a sense of "feeling like a scientist." The results imply that practitioners both in and out of the classroom should privilege agentic use of tools when working with all learners, but especially girls. Further, the types of material resources selected in learning settings are critically important, as different types of material resources afford different types of identity work. In particular, using materials that hold disciplinary authenticity, when coupled with learning about how scientists use those same instruments, helps girls "feel like scientists," an important part of becoming a science apprentice.

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Introduction

Climate change is particularly pronounced in the polar regions, with impacts such as range shifts among species, reduction in duration and extent of ice, and a host of other changes now in evidence (Larsen et al., 2014). It is widely acknowledged that a diverse scientific workforce is a critical aspect of solving the climate-related socioecological problems we now face (President's Council of Advisors on Science and Technology (PCAST), 2012), yet many sciences are still male-dominated. For instance, women make up only 28% of the workforce in the physical sciences, including geosciences (National Science Board, 2018). It remains a challenge for the field to bring women into these careers. At the heart of the challenge are questions of identity and feelings of belonging during youth (summarized in Archer et al., 2010). It has been documented over and over that classroom and societal stereotypes of "who does science" and what it means to do science, particularly with respect to physical sciences, can limit feelings of belonging and a desire to pursue a STEM career among girls. For instance, draw-a-scientist tests have revealed that girls persistently perceive scientists as male (Chambers, 1983; Finson, 2002). Other stereotypical ideas about science include the idea that some sciences are isolating, and that they do not address societal issues of importance (reviewed in Cheryan, Master, & Meltzoff, 2015). Because girls are known to value work that is cooperative and socially relevant (e.g., Miller, Blessing, & Schwartz, 2006) these perceptions can lead girls away from science. Research also illustrates that school science marginalizes girls through deficit-based enactments that frequently portray science as "for boys," and often does not address the interests and concerns of girls (Calabrese Barton, Tan, & Rivet, 2008).

In contrast to dominant learning paradigms and stereotypical ideas about science frequently experienced in school and society, situated learning experiences (those where learning takes place in authentic contexts; Lave & Wenger, 1991) allow learners to participate in science culture and practices in meaningful ways that are relevant to the learner and embody characteristics of real science settings. Thus, such experiences have the potential to support the development of a science identity among girls. In particular, the

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research apprenticeship model is a design where learners deeply experience disciplinary practices with guidance from mentors who are experts in the field (Barab & Hay, 2001), participating in experiences in which they have agency, and resulting in increased understanding of the nature of science, increased confidence and self-concept in science, and other positive outcomes (reviewed in Sadler, Burgin, McKinney, & Ponjuan, 2010). In this model, learners engage in authentic practices of science, or those that hold disciplinary authenticity. We adopt the definition of disciplinary authenticity proposed by Watkins, Coffey, Redish, and Cooke (2012, p. 2) as activities that use tools "in ways and for purposes that reflect how the disciplines build, organize, and assess knowledge about the world." Disciplinary authenticity is an integral part of communities of practice (Wenger, 1998), which have three aspects: 1) domain (includes a common purpose and joint knowledge about a disciplinary domain and the ways in which it functions); 2) practice (includes a shared repertoire of tools, ways of approaching problems, and experiences); and 3) community (includes engagement in discussions, and working in ways that foster domain-related relationships). In these apprenticeships, learners are characterized as "legitimate peripheral participants" (Lave & Wenger, 1991) in which they start out as novices, gaining familiarity, comfort, and increasing expertise with the domain and practices valued by members of the science community of practice.

In such circumstances, practice-linked identities, or a sense of deepened connection to practice (Nasir & Hand, 2008), often develop. Sociocultural theories of learning have long recognized that learning, including identity development, is inseparable from the place and context where the learning occurs. For instance, the cultural learning pathways theory (Bell, Tzou, Bricker, & Baines, 2012), describes the building of identities over time through cascading experiences in which positionality of participants, actions taken in the setting, and the places where the learning happens, including the materials present, interact. In the same vein, Nasir and Cooks (2009) specify three aspects of practice-linked identities: material, ideational, and relational, which intersect during learning experiences. As per Nasir and Cooks (2009), physical artifacts within the environment make up the material resources; relational resources are those interpersonal relationships with instructors, mentors and peers in the setting; and ideational resources are ideas about oneself and place in the practice and the world.

Studies of research apprenticeships often invoke sociocultural frameworks when exploring identity development. While acknowledging that a variety of identity resources are at play, most of these studies focus more on the cognitive-ideational or social aspects of the learning setting (e.g., Burgin, McConnell, & Flowers, 2015; Hunter, Laursen, and Seymour, 2006; Kapon, 2016; Riedinger & McGinnis, 2017). Material resources such as artifacts, specimens, tools, and instruments used for scientific investigation, are often mentioned as valuable resources for learning science in the context of a research apprenticeship program. However, the ways in which these resources afford learning, in the sociocultural sense, is not clearly specified in the literature, particularly with respect to identity development (the Nasir and Cooks framework, for instance, describes material resources associated with track and field, rather than scientific tools in the context of a research apprenticeship program). We argue here that such resources may be especially consequential in research apprenticeships for girls, as tools, settings, and clothing related to apprenticeship experiences are abundant and frequently hold disciplinary authenticity, and thus may contribute to a sense of legitimate peripheral participation and a sense of belonging in the science community of practice.

In this paper, we take up the broad question of *what kinds* of material resources allow science apprentices to engage in *what kinds* of identity-related work. We explore this question in the context of a two-week summer research apprenticeship program for girls that was co-designed by geologists, geophysicists, biologists, and learning scientists, centered around fjord and riverine ecosystems of the far north, and the life histories of focal species (harbor seals and salmon) in those habitats.

Theoretical framework: Material resources for identity work through apprenticeship

We take up identity work in the contexts of apprenticeship and community of practice, in relation to youth's consideration of possible future selves (Markus & Nurius, 1986) in the sense of authoring a self (Holland, Lachiotte, Skinner, & Cain, 1998). We use the notion of identity work to acknowledge the fluidity of identity as multidimensional and contextually adaptive (Lee, 2017), with the conception that identity involves a sense of self in the present and consideration as to who one might want to become in the future. Such identity work comes in response to "the actions that individuals take and the relationships they form (and the resources they leverage to do so) at any given moment and as constrained by the historically, culturally, and socially legitimized norms, rules, and expectations that operate within the spaces in which such work takes place" (Calabrese Barton et al., 2013, p. 38). We considered the research apprenticeship a time to "try on" an identity in a way that the youth can more deeply understand the kinds of roles and tasks available to individuals within a figured world and what it takes to be a kind of person who participates in, contributes to and constructs a community of practice.

In the apprenticeship model of science learning (Barab & Hay, 2001), a novice learns under an expert's tutelage, using tools in the environment where the experts carry out their practice, while engaging in science in which the expert and the apprentice have a vested interest. This goes beyond a typical classroom investigation, in which students situationally adopt a subset of science practices in the short term that may or may not resemble how science is done in the lab or field. Instead, the immersive approach to science learning that occurs in a research apprenticeship presents an opportunity for the novice to gain "insights into the communal nature of science and may facilitate the learner's adoption of ways of perceiving and interacting with the world that are consistent with those of real scientists" (Barab & Hay, 2001, p. 71). By apprenticing and engaging in identity work, individuals can envision new possible selves (Markus & Nurius, 1986), which feeds back into further participation, deepened social relationships, and over time, can result in identification with STEM. The resources available in the learning setting have important consequences for novices' trajectories of participation, learning, and identification.

Material resources come to the fore as the means via which research is conducted. The authentic practices that scientists engage in to do their work closely mirror the recommendations for science learning presented in National Research Council (2012): asking learners to pose their own questions, plan and carry out investigations, analyze and interpret data, and engage in argument from evidence. We point out here that scientists and learners alike must plan which data to collect, and collect the data itself, in order to have anything to analyze and interpret. In science, data collection can be nontrivial, sometimes requiring special expertise with advanced instrumentation, or in cases where instruments and tools are less complex, requiring at least a comfort and familiarity with how a piece of science equipment operates. If an apprentice is to adopt authentic practices of science, she must travel a path in which she becomes an empowered user of the tools with which data is collected. Similarly, apprentices might literally don the "trappings" that signal membership in a science community, such as hip waders for a stream biologist, or a lab coat for a chemist, in order to carry out the valued work of the community.

This process of adopting and using material resources is part of the shared repertoire aspect of a community of practice, which includes domain-specific tools, ways of approaching problems, language, symbols, and processes (Wenger, 1998). This concept, that the appropriation of material resources is not context free, but instead is embedded in a sociocultural matrix, is also found in the concept of "cultural tools" such as language, symbols, and physical objects, that are seen to mediate "what and how we think" (Jakobsson & Davidsson, 2012, p. 6). In turn, this idea has its roots in the work of Vygotsky (1978), who argued that material resources ("artifacts") mediate cognition itself. Thus, the affordances of instruments and tools, and the ways in which they are taken up by apprentices, depends on the ways in which the tools and the learners are positioned, and may impact the social pathways into or away from identification and learning in science (e.g., Calabrese Barton et al., 2013; Tzou, Scalone, & Bell, 2010; Van Horne & Bell, 2017). Such studies often demonstrate how relational resources provide or restrict access to material resources (e.g., Barron, Martin, Takeuchi, & Fithian, 2009; Jones et al., 2000) that can support learning. For instance, Jones et al. (2000) showed that how the "tool space" is configured in terms of resource availability and discourse has important implications for the ways those tools are used.

In addition to these factors, we argue here that learners might experience material resources in different ways because of the nature of the materials themselves. Material resources include a host of things, from specialized tools to the setting of science itself. When science is conducted in the field, the physical settings and/or the specimens encountered there might serve to engender emotional connections due to having an awe-inspiring experience in nature (Carsten Conner, Perin, & Pettit, 2018; Mogk & Goodwin, 2012). Conversely, complex instruments and technology are sometimes experienced as alienating and dehumanizing (although everyday technologies such as iPhones might be expected to bring a sense of personal relevance). Without the mediating influences of socializers who support learning trajectories in positive ways, complex tools that necessitate "onboarding" time to learn to use might be experienced in a negative way. Clearly, a consideration of the affordances of various material resources includes thinking about how novices come to use the artifacts and tools in an increasingly expert way, and with a growing sense of ownership and agency.

Taking all of these factors together, our more focused research question was: "How does engaging with various material resources influence aspects of science identity work for girls?"

Context of the study

The study took place in the context of the Broadening Interest in Geosciences, Habitat, and Technology (BRIGHT) Girls project. The program integrates biology, geology, and technology during a research apprenticeship program for high school-aged girls. It has been documented that girls tend to be more interested in biology than in many physical sciences (reviewed in Brotman & Moore, 2008). Therefore, the academy makes explicit interdisciplinary connections between these fields in order to make the content more relevant to girls' interests and concerns (with the caveat that these are documented patterns, but that not every girl shares these interests). Guiding the overall model are key principles of a research apprenticeship: participants conducting authentic science (including scientific tool use) alongside practicing scientists. The design offers an experience in which the participants can develop a vision of what scientists in varying disciplines do, what they value, what they talk about, how they act, and who they are by training and immersing the girls in laboratory and field-based practices and settings.

The present study investigates two academies that took place in a single summer, one held in a primarily riparian ecological area in the interior of Alaska, and another in a tidewater fjord in a coastal community of the state. Each academy took place over a period of ten days. The participants learned about and performed novel research related to life history, ecology, and river or glacial habitat using a combination of remote sensing techniques, direct observation, and data collection during day trips to local rivers or fjords. In one location, the focal species was the harbor seal, while in the other location, the focal species was salmon. In both places, the girls were outdoors and on the water extensively, using a range of watercraft.

Specific strategies were designed into the academy to promote the participants' identity work with the disciplinary domains (biology, technology and geosciences), such as providing relatable role models; authentic, societally relevant science experiences; agency to participants; and positioning participants to become experts. Key design commitments included:

1. Positioning girls to have agency in generating and investigating a scientific, researchable question within the constraints of the academy, like that of any field science experience;
2. Placing instruments, tools, equipment and other resources necessary for field and laboratory work in the hands of the girls, as well as decision making as much as possible, to facilitate the learners' agency with scientific practices;
3. Including both field and laboratory science experiences;
4. Having girls work under the tutelage of practicing scientists in each of the fields as mentors and instructors.

During the first 5 days of the academy, the participants were trained in the use of scientific instruments and other science resources, and engaged in activities that helped them actively gain domain knowledge about the focal species and their habitats. The girls learned how to use a range of scientific tools, including a secchi disk (turbidity), a YSI probe (oxygen, temperature, and conductivity), a hydrophone (underwater sounds), a Marsh-McBirney flow meter (water velocity), a CTD (conductivity, temperature, depth) probe, a GPS unit (geolocation), a kick net and sorting trays (invertebrate sampling), a thermography camera (temperature), rock hammers, hand lenses, binoculars, and radio telemetry equipment (radio tag detection). They also gained skills with material resources that were not specific to science but were needed to conduct the investigation and exploration of the riparian or fjord habitats. Girls donned chest waders in order to enter the river and take measurements, built their own instruments using power tools, performed a dissection or necropsy, and used canoes or other boats to explore the field environment and during their data collection activities. The participants progressed quickly from engaging in activities as science learners in the first week to authors of their own research investigations in the second week. With mentor facilitation, the girls were set the task of posing and refining participant-generated research questions, and designing methods to answer these questions. The girls completed their research investigation by collecting field data, analyzing the data, and interpreting their findings. The academy capped with the girls presenting their research project to their families and to a broader community of scientists from the university and local research centers, which was intended to affirm membership in the community of practice.

Over the course of the academy, the group moved through a university classroom, biology laboratories, outdoor spaces, and on the final day, a lecture hall where the participants presented their research to the public and the university community. The classroom space was configured as little like a classroom as possible in order to shift the participants' thinking about themselves as students to professional colleagues. The room had moveable tables and chairs, and the participants had the freedom to move throughout the space. Laboratory space included a fisheries dissection room or a necropsy room. The outdoor sites, depending on the program location, included beaches, rivers, forests, lakes, and fjords.

Scientists worked with the participants for the duration of the academy. These STEM professionals included remote sensing scientists, marine ecologists, geologists, seal biologists and fisheries biologists. The primary mentor for each group held a graduate degree in a natural science field; thus, all primary mentors had extensive expertise in their field. There were four primary mentors in each academy who were present for the entire academy, each of whom worked with a group of 3–5 girls, depending on the activity. A number of additional mentors, ranging from undergraduate students to full professors and/or practicing government scientists, often assisted with particular activities, each attending only parts of the academy. The large number of mentors available provided a great deal of attention and interaction, plus a range of personalities and interests for girls to find a person with whom they related, and in whom they could see a role model.

Participants

The participants included in this analysis include the 27 girls who took part in the program during the summer of 2017, who gave assent and had parental assent to participate in the research (in total, 16 girls from one site and 15 girls from the other site participated in the academy, but 4 did not assent to participate in the research). The research participants were high school aged, ranging from 13 to 17 years (5 thirteen-year olds, 11 fourteen-year-olds, 4 fifteen-year olds, 4 sixteen-year-olds, and 3 seventeen-year olds). The demographics for these girls are as follows: 4% Asian, 22% Alaska Native or American Indian, 4% African American, 70% Caucasian; 33% low income; 33% would be first generation to earn a bachelor's degree if they later enroll in college. All names are pseudonyms. The participants were recruited from middle and high schools near the two host sites, which are located in medium-sized urban towns. Several participants elected to travel from neighboring rural communities to attend. The girls were asked to indicate their interest through an online application, although girls were only turned away if capacity had been reached in the camp.

Methods

Design and data collection

We took a qualitative, participant observer approach to the research, with all authors participating in the design and instruction of the academy, as well as the research, to varying extents. The value of the participant-observer approach lies in its ability to give researchers an "insider" view of the experience of the participants while reducing reactivity, or

Table 1. Final set of affordance codes, definitions, and examples.

Identity-related affordance	Definition	Example from interview data
Affect toward science or science-related experiences	Emotion about an experience is expressed (coded for either positive or negative emotions).	"I really liked yesterday, getting all the data and like, being in waders and just going in"
Opening up new science-related interests	New kinds of science-related interests (e.g. geology vs. biology, field vs. lab).	"Geology is not as boring as I thought it would be … I like how you can tell just how old it was by looking at it."
Feeling like a scientist	Statements of feeling like a scientist.	"I think it's because we got to learn what real scientists actually do when they go out into the field and how they work out in the field. And … learn how to use the instruments they use, and … I don't know, just become a mini scientist."
Science learning	Learning about what science is or how it is done, or deeper conceptual understanding (not just learning a science "fact").	"I enjoyed being on the boat, but I think maybe it was a little long … It's just some things, because of the scientific process, take a longer time."
Career-related outcome	Thinking about new careers or reinforcing existing ideas about science-related careers.	"I just had a recent experience … [that] made me want to be a doctor … either that or I want to be a chemist, and I think coming here like talking about how you step around in the water like when we went to the lake … like how it starts a chemical reaction."
Science self-efficacy and confidence	Related to how someone thinks about their ability in relation to science.	"I feel like my science skills have improved 1,000 percent … before, it was like, um, maybe, but now it's just like heck yeah."

the threat that participants may respond in a particular way because they are aware they are being studied. The participant observer approach acclimates the participants to the presence of the researchers; thus, involvement by the research team in the entire arc of the academy likely reduced reactivity, as the researchers were part of the everyday setting (Cohen, Manion, & Morrison, 2007). Validity and reliability were increased through investigator triangulation and by our approach to analysis, which included examining interrater reliability (described below).

The data used in the present study derive from interviews conducted during the final day of the summer academy. The interview protocol was constructed in a way to elicit the ways in which different aspects of identity work may have occurred and why—for instance, we ask "Was there a time during the academy that you felt like a scientist? (If yes, prompt: What made you feel like a scientist?). Other questions were constructed similarly, around the main areas associated with identity work in the context of a community of practice, such as domain-specific learning and ideas about science, a sense of belonging in the community, a sense of science-related self-confidence, and others (Bell et al., 2012; Lave & Wenger, 1991). During review of the interview transcripts after the conclusion of the first year of the program, we noted that participants' responses to interview questions often included references to using instruments and donning specialized clothing for field or lab work as things they enjoyed or that helped them learn. In the subsequent summer academies, we modified the interview questions to further probe about those areas. The final interview protocol appears in the online supplementary material. Three interviewers conducted the interviews. The interviews ranged from 15 to 30 minutes in duration and were audio-recorded and transcribed.

Analysis

Our analysis focused on understanding the affordances of the material resources offered by the BRIGHT Girls program with respect to identity work conducted by participants. We used a directed qualitative content analysis approach (Hsieh & Shannon, 2005; Merriam, 2009) to develop codes that defined both *identity-related affordances* and *specific material resources*. In this approach, initial codes are derived from theory and then refined as the codes are applied to the data. We then cross-tabulated the affordance codes with the material resource codes in order to look for significant patterns of co-occurrence.

For identity-related affordances, we drew from the same set of concepts used to create the interview questions, creating an initial list of codes such as "interest," "ideas about science," and "career-related." These codes were influenced by literature that describes science identity and learning pathways (e.g., Bell et al., 2012; Lave & Wenger, 1991). The authors independently created, then discussed, memos and initial codes, which were independently applied to a subset of the data using Dedoose software. We underwent several additional rounds of coding in which we added, grouped, or eliminated codes. Our final set of affordance codes, along with definitions and examples, appears in Table 1. We applied affordance codes in a mutually exclusive way—that is, each author was tasked with applying only a single affordance code to an individual excerpt. To establish interrater reliability, each author independently applied the final codes to a subset of data. Because there were three raters, we used free marginal multi-rater kappa ($k = 0.80$) rather than Cohen's kappa, which is only appropriate when there are two raters (Randolph, 2005).

To develop material resource codes, we drew from the Nasir and Cooks (2009) definition of material resources (physical artifacts in the environment, including the setting itself) to create a list of material resources that were included in the design of the academy. The initial list included disciplinary tools such as the YSI and secchi disk (which were later collapsed into an "instruments" code); "specimens" such as living seals, preserved salmon, and icebergs; physical setting, and specialized clothing. After initial rounds of coding, "artifact" was added as a category to represent human-made physical artifacts that were important in carrying out the work of science, but which were not strictly scientific instruments. Our final code list for material

Table 2. Final set of material resource codes, definitions, and examples.

Material resource code	Definition	Example
Instrument	Specialized instruments and tools for data collection.	YSI water sampler, hydrophone, secchi disk, Marsh-McBirney flow meter
Specimen	Physical specimens in the natural environment or laboratory with which the girls interact such that the specimens are involved in the doing of scientific work. Specimen is an individual or part of an animal, plant, rock, piece of a mineral, etc., in scientific study.	Seals, salmon, iceberg, rock
Artifact	Human-made objects that enable or are involved in scientific work but are not exclusive to a science practice (contrast to instrument). Data are included in this because they are inscriptions that represent the natural world.	Notebook, computer, boat, data
Specialized clothing	Clothing used to support the scientific work.	Chest-waders, lab coats, nitrile gloves
Physical setting	Environment or site (natural or human-made) where scientific work takes place.	Laboratory, river, glacier, fjord

Table 3. Percentage of times each type of material resource was mentioned in tandem with a particular outcome. Items in bold, larger text are the most commonly occurring outcomes for each type (data should be read in columns).

Outcome	Instruments	Specimens	Artifacts	Specialized clothing	Physical setting
Affect toward science or science-related experiences	**25.0%**	**47.6%**	**44.4%**	33.3%	**55.0%**
Opening up new science-related interests	0.0%	4.8%	0.0%	0.0%	0.0%
Feeling like a scientist	**32.5%**	19.0%	26.7%	**66.7%**	15.0%
Science learning	**22.5%**	16.7%	20.0%	0.0%	25.0%
Career-related outcome	10.0%	4.8%	2.2%	0.0%	5.0%
Science self-efficacy and confidence	10.0%	7.1%	6.7%	0.0%	0.0%
TOTAL	100%	100%	100%	100%	100%

resources collapsed several specific types of resources into a larger parent code (Table 2), while still keeping the specific resource listed as a child code. Material resource codes were not always mutually exclusive, as some excerpts referred to more than one resource simultaneously (e.g., "I liked going out on the boat on the river" would involve both an artifact and a physical setting code). Importantly, all of the types of resources were available to girls in both academies, even if a specific sub-resource type varied (e.g., girls in one location studied seals in a fjord habitat, and in another location studied salmon, in a river habitat, but both seals and salmon fell into the "specimen" category, and both river and fjord fell into the "physical setting" category). The design of the academies was fundamentally the same in both locations; thus, exposure to each category of material resources was roughly the same in both locations (e.g., both locations privileged the use of instruments in outdoor environments; both used boats, both involved a dissection or necropsy, etc.).

Once we coded all data for instances of affordance codes and material resource codes, we used Dedoose to locate excerpts where affordance codes co-occurred with material resource codes. We report the co-occurrence results below, and then turn our attention to what was going on in these moments to make specific material resources salient in the moments that the girls described.

Results

In total, there were 186 counts of a particular material resource intersecting with a particular affordance code. As described above, in some cases more than one material resource code was applied to the same excerpt; thus, some excerpts appear in more than one category (for instance, a particular excerpt with an "affect" code might co-occur with both "artifact" or "physical setting").

In this study, we were most interested in elucidating *what types* of material resources were associated with *what types* of affordances. To look for patterns in terms of associations, we calculated the percentage of times each resource was mentioned in tandem with a particular outcome (Table 3). Some clear patterns emerged, with "feeling like a scientist" as the top affordance associated with instruments and specialized clothing, and "affect" as the top affordance associated with specimens, artifacts, and physical setting. Below, we discuss each type of material resource, focusing on what was going on in the moment the girls mentioned in order to understand how the outcome came about. For most types of material resources, the top outcome was vastly more common than other categories; therefore, only the top outcome will be discussed. However, in the case of instruments, the affordances were more balanced across categories in terms of percentages; thus, we discuss the top three affordances associated with instruments.

Instruments

Instruments were most frequently associated with "feeling like a scientist," (32.5 percent of "instrument" excerpts) although a significant portion co-occurred with "affect toward science" and "science learning." (25% and 22.5%, respectively). In particular, in responses to the interview question about what made them feel like a scientist, girls called out the authenticity of the instruments, as in the quote below:

> Janine: Well, we didn't know about the equipment we were using was actually used by scientists earlier that month. Like it was the same equipment that real scientists have gone through

school to become scientists, they were actually using the same devices we were.

Instruments were also important for engaging in authentic science-related problems that come up frequently in the field, such as malfunctioning instruments. As the girls encountered this problem, they heard stories from the mentors about their own challenges and solutions, which helped inspire the girls as they worked through their own instrument issues. Comparing this experience to that of their mentors made the girls feel more like this was akin to that of scientists. For example, Beth's group was unable to collect data at several locations because an instrument broke on the cruise. The group had to improvise an alternate data collection method to suit their research question, and their mentor shared stories about instrument failures while doing fieldwork. Beth refers to this experience in the quote below:

> Beth: Yeah, working with all the equipment on the boat. That was cool learning about what it's like on a science vessel. And, also, we learned – people talked about their experience on science trips on a boat. So, it was kind of comparing our experience to that, and it makes us feel like scientists.

Learning through using scientific instruments had novelty and led to a sense of ownership as the girls became more familiar with how to operate them. The girls had a growing sense of involvement in the community of practice as they were positioned as "tool" experts. Feelings of being engaged in an "exclusive" community further underscored these feelings. In the quotation below, Lucy notes that she enjoyed collecting data because she used scientific equipment other people wouldn't know how to use:

> Lucy: ….Whenever we were actually got, like collecting data is when I really feel like a scientist.
>
> Interviewer: So what about collecting data makes you feel like a scientist? Because of the things you're doing? The experience?
>
> Lucy: I mean you have this scientific equipment and it's just cool because most people wouldn't even know what it did. So that alone makes me feel like oh, I know what this is and I know what I'm finding and I know what this could do for me. So it was just, yeah. Like even something like the secchi disc, it looks just like this little round thing, but you have to know what you're doing. Also the Marsh- McBirney [flow meter] I liked that.

As seen in the above quote, "artifacts" were frequently referred to in tandem with "instruments." In these cases, the girls particularly noted that collecting data and deciding how to organize it made them feel like scientists, and that gave them ownership of their science investigations. For instance, one girl contrasted the experience with that of school. She asserted that the data collection process allowed her to feel like a scientist, rather than being given a data set and being asked to analyze it:

> Interviewer: So, what were some of the things you were doing when you were feeling like a scientist?
>
> Sandy: Just taking data samples. That was really cool, 'cause normally—you don't normally do that in science class normally they have all of the data out for you and you just have to do the math and figure it out on your own, but we actually got to do the full process which was really cool.

"Science learning" was another area that occurred frequently in tandem with instruments. We conceptualized the science learning code as learning about the nature of science—how science is done, what procedures are used, and the ways in which scientific practices are carried out. This concept echoes the "domain" element of a community of practice as described by Wenger (1998). Girls noted a variety of ways in which instruments impacted science learning. One girl noted that working with instruments allowed her to learn that "not everything goes as planned" in science and alluded to the fact that you have to be flexible with data collection in a field context. Another girl noted that using the instruments really increased her understanding of science in a way that doing "school science" did not. Yet another noted the way that using instruments allowed her to understand *how* scientists get data:

> Lucy: I really enjoyed like all the field work probably like just learning how to like, you know to see simple instruments that like, you know, it's simple, just how much you can learn from them, and I just – was really cool learning about, you know, what biologists are using like out in the field because you always hear about all this data but you never hear about how they get it kind of stuff.

Finally, affect toward science was an area that frequently co-occurred with "instruments." In our analysis, both positive and negative affect were coded to consider if particular types of material resources inspired or dissuaded connection. Overall, we saw a few examples of negative emotions surfacing in relation to particular material resources. However, surfacing much more frequently were instances in which girls indicated liking or having other positive emotions with science experiences associated with particular material resources. In terms of instruments, girls frequently reported that they really enjoyed using the scientific instruments, citing the novelty or fun of the experience as important for their connection. One girl discussed her frustration with instruments when they were not working properly.

Specialized clothing

The specialized clothing resource, like instruments, was most frequently associated with "feeling like a scientist" (66.7 percent of "specialized clothing" excerpts). During the apprenticeship, the girls donned lab coats specifically to perform salmon dissections or seal necropsies; thus, many of the clothing-related excerpts were also tagged with "specimen" codes. As girls discussed the ways in which donning a lab coat during the dissections and necropsies made them "feel like a scientist," it became clear that many girls activated scientist stereotypes when referring to their relationship to the activity:

> Interviewer: Was there a time during the academy that you felt like a scientist?
>
> Michelle: Oh, yeah. Oh, yeah, like all the time. Especially when we were doing that necropsy, we got to handle everything and

> we had these like very official lab coats but they weren't really lab coats they were just like white cloth.
>
> Interviewer: Oh, the Tyvek.
>
> Michelle: Yeah, the Tyvek and we had like the gloves and the safety goggles and I'm just like I am so a scientist. And at the end of it all when I was completely covered in seal blood I got so many pictures of me just being devious and like doing mad science stuff just 'cause it's funny. That was fun.
>
> Interviewer: You felt like a scientist then?
>
> Michelle: Yes.

Interestingly, rather than pushing them away from the activity, embracing the stereotype seemed to be a positive experience for them. They connected to the idea of being a scientist through adopting the symbolism of the lab coat.

Specimens

Specimens were most frequently associated with the "affect" code (47.6 percent of "specimen" excerpts). Within this category, seals were the most frequently called out specimen type that girls enjoyed, although salmon were mentioned several times, too. Interacting with harbor seals, either through observing living seals or interacting with seal specimens during the necropsy, inspired a lot of positive emotion among the participants. No instances of negative affect associated with seals were noted. Girls highlighted learning about seal anatomy and seeing "what's in them." Simply observing the seals, and learning about their life histories, tended to be something girls described as "amazing" or "cool." In this way, the seals served as an important focal point from which to engage with the science of the academy.

> Michelle: …the anatomy of the harbor seal was pretty cool. I already knew the anatomy but just kind of taking a deeper look at that and the fact that harbor seals are so ferocious. Ferocious? Vicious and ferocious. You know what I mean. They're very dangerous to humans. But they're so cute they just look you can give them a belly rub and make them a little sweater. You just want to hold them and hug them 'cause they're little sausages. They're adorable.

Artifacts

Like specimens, artifacts were most frequently associated with the affect code (44.4 percent of "artifact" codes). With respect to artifacts, the experience of being on a boat was highlighted the most as something that girls enjoyed. In some cases, the girls talked about simply being on the boat as an enjoyable or novel experience, while in other instances, "artifact" was inseparable from "physical setting," as boats opened up the opportunity for being "on the water," which in turn afforded opportunities to conduct science, as seen below in the "physical setting" category.

Physical setting

Like specimens and artifacts, the physical settings were most frequently associated with the affect code (55 percent of "physical setting" codes). With respect to physical setting, most girls enjoyed conducting science outside in a field setting (two girls did not enjoy the hiking involved in getting to the field site). A few girls noted that they enjoyed experiences in the laboratory setting. Girls commented on enjoying the science expeditions because they got to be outdoors "in the field." Some girls contrasted the experience of conducting the field and laboratory science in the academy with the science they do in school, describing the academy science as more "hands-on" and highlighting the opportunity to go into the field:

> Amber: "It's pretty different. In science class, you don't go out onto a boat; you rarely go out onto a beach. And just to like collect samples and things, take notes and stuff. That was a pretty refreshing change."

Discussion

We set out to examine how material resources impact the learning, in the sociocultural sense, that occurs during a research apprenticeship program for girls. Our findings indicate that different kinds of material resources have the potential to support different kinds of identity-related affordances. It is important to note that the material resources that were part of this experience, as is the case in any learning setting, were not experienced in a context-free way, but instead were mediated through interactions with the scientist mentors. In turn, specific design commitments, such as putting the tools into the hands of the girls (agentic tools use) rather than having instructors use the tools on behalf of the girls (and thus holding the power), guided these social interactions.

With respect to the patterns we saw, specialized clothing was most often associated with "feeling like a scientist" as compared to other types of affordances, while specimens, artifacts, and physical setting were most often associated with "affect" as compared to other affordances. As noted above, the associations for instruments were more varied, with "feeling like a scientist" as the primary association, but closely followed by "affect" and "science learning."

We now turn our attention to interpreting these patterns, starting with specialized clothing. The ways in which a person views her or himself in relationship to a discipline is critical to whether or not that individual ultimately comes to adopt a disciplinary identity as part of their larger identity. The moments that the girls identified in the academy in which they felt like a scientist represent times in which they were able to "try on" what it feels like to act and think like a scientist in practice—when putting on a lab coat or waders, this entailed *literally* trying on the trappings of science and situationally adopting the symbolism associated with lab coats. The question of whether these feelings were internalized over time remains open, but even situationally-inspired feelings of "feeling like a scientist" can give important glimpses into identity development. This finding may have particular consequences for working with girls in practice. It is frequently suggested in the literature that the stereotypical image of the crazy scientist in a white lab coat is distancing to girls (Chambers, 1983; Finson, 2002). Our findings suggest that this pattern may be a bit more nuanced and that perhaps some stereotypical trappings of science can be used to positive effect when coupled with opportunities to apprentice in settings that are designed with specific and extensive identity supports in mind. In particular, we suggest that lab coats may have special import for this purpose because of their very commonality as a symbol of science—that is, while waders might be a "tool of the trade" for a stream biologist, for instance, they are not necessarily portrayed symbolically in society as "scientific gear."

With respect to specimens, artifacts, and the physical settings of science, we saw that these aspects were sometimes inseparable, but that each had impact. In particular, working with live seals and deceased seal specimens, as well as working in authentic field sites, particularly in the context of work from boats, inspired emotional connections to science. This is similar to the experience of practicing scientists, as disciplinary practice is permeated with affect (Carsten Conner et al., 2018). Scientists often acknowledge the ways emotional connection drives their work through, for instance, the pleasure of studying phenomenon, esthetics or empathy associated with the subject matter, cognitive challenge, or feelings involved in scholarly interactions (Hamza & Wickman, 2009; Jaber & Hammer, 2016). Similarly, learners can have early (positive) affective experiences that pique interest or personal connection to an experience or object, which can in turn drive repeated engagement (Hidi & Renninger, 2006) and initiate the identity pathway. Establishing such connections may be particularly consequential for girls, who often do not see classroom science as relevant to their lives or connected to their interests. Conversely, negative affect associated with an experience can introduce or reinforce dislike of an experience and reduce motivation or interest. Thus, when designing learning experiences, educators might carefully think not only about the types of material resources to make available in the setting, but also when to make them available. Resources that are tightly linked with positive affect, for instance, might be especially salient early in the learning trajectory.

Perhaps most notable of all, the scientific instruments that the girls worked with during the academy were associated with enjoyment, deep knowledge of what it takes to do field science, and inspiration for the girls to feel like scientists themselves. It has long been suggested that using tools authentic to science is a key part of apprenticing learners to science (Barab & Hay, 2001). Tools embody scientific practices; they are frequently inseparable from the type of data collected. Certain types of biological work, for instance, can hardly occur without the presence of a pipette to precisely measure microscopic quantities of reagents. Similarly, the girls experiencing the BRIGHT Girls summer academy discovered that their access to the "data" that they prized was tool-dependent. Learning to use the instruments – as the "content of the learning" noted by Nasir and Cooks (2009)—fostered in the participants a more nuanced understanding of the limitations of the instruments and of the data that they collected.

In turn, the data represented answers to questions that they generated during the academy. Using the instruments also inspired a sense of "specialness," or membership in an exclusive group—that of the practicing community of scientists. Part of the identity work of feeling like a scientist included experiencing the cognitive and affective associations (Jaber & Hammer, 2016) that authentic scientific practice entails.

It is important to note that the design of the academy prioritized putting the tools into the hands of the girls throughout the experience and positioned them along a pathway from supported novices in the first week to acknowledged tool "experts" in the second week. Without such positioning, it seems unlikely that these outcomes would be the same, given that learning occurs in a sociocultural matrix in which the setting, and the social relationships forged there, are inseparable from the learning that takes place (e.g., Bell et al., 2012).

Implications

While the learning and identity affordances associated with material resources described here are likely not unique to girls, it may be especially important for girls to experience agentic use of tools. Classroom teaching practices have been noted to exacerbate and reify gendered access to materials, where boys tend to control access and use of physical tools in mixed-gender group laboratory settings (Carter, Westbrook, & Thompkins, 1999). Girls also can be less likely than boys to tinker or play with science tools and can be more likely to straightforwardly follow teacher directions, resulting in a lack of understanding of the properties and functions of those tools (Jones et al., 2000). Girls may decline to engage in such tinkering because such risk-taking makes them less likely to achieve the "good student identity" common to girls (Carlone, 2004). Thus, agentic tool use in out-of-school learning settings could be all the more important as an opportunity for science identity building, which in turn may help diversify the science work force of the future.

Implications for practice include privileging use of tools during science experiences, whether in or out of the classroom. Access to material resources is important because their availability or lack thereof shapes disciplinary identification in different ways. The types of material resources selected are also critically important, as different types of material resources afford different types of identity work, as seen in our results. In particular, using materials that hold disciplinary authenticity, when coupled with learning about how scientists use those same instruments, helps girls "feel like scientists," an important marker in an apprenticeship trajectory.

Limitations

Our work was conducted in a single sex format. It is well-documented that girls' gendered identities can sometimes conflict with science identities (e.g., Archer et al., 2012), and some studies have indicated that girls (and boys) report feeling more relaxed and comfortable in a classroom without the other sex present (reviewed in Parker & Rennie, 2002). To the extent that a necropsy, or donning unflattering clothing, conflicts with their gendered identities, the girls in our study may or may not have as readily donned scientific clothing, with all that entails, in a mixed-gender group.

We acknowledge a limitation of this study was that it was conducted in a highly mentor and material-rich setting with access to vast science expertise and resources, and thus the findings may be limited in their generalizability to other learning settings. However, the focus on agentic use of authentic tools is likely to be impactful in other hands - as long as practitioners are aware of the importance of agency and how to promote it. For instance, tools such as water quality kits, specialized dissection tools, and classroom-level sensors, which might be a bit more "special" than everyday tools found in the classroom, could be put in the hands of students to answer student-generated, authentic, and personally relevant science questions to similar effect. It is a lingering question of how "authentic" to professional science the material resources need to be for learners to engage in identity work, even if content outcomes are achieved. Given the economic constraints and limited science expertise available in many learning settings, future studies might take up this question.

Conclusion

It has long been known that material resources are part of learning in the sociocultural sense. However, the ways that research apprentices take up materials during science learning has rarely been examined. Our results show nuanced patterns in the ways that different categories of material resources afford different types of identity work, with important implications for the design of science learning environments.

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