12. Learners' Perceptions of Participating in STEM Hands-On Activities in an Out-Of-School Community-Based Organization Program

AREEJ MAWASI, RUTH WYLIE, AND ELISABETH GEE

Abstract: This paper investigates the potential for STEM hands-on activities to support adolescents' (5th and 6th grade) participation in STEM practices in an out-of-school community-based organization in an Arab town in Israel. In this study, we observed 4 hands-on activity sessions (total time = 395 minutes) at Al-Rowad for Science and Technology, a community-based organization for STEM education. In addition, we conducted interviews with the 10 participants to understand their perceptions of their learning processes and their perceptions of the activities. When prompted to describe the activities, procedures, outcomes, final products, and their learning process, learners responded in diverse ways. Our analysis reveals 3 findings: (a) These activities show potential for helping learners connect STEM practices to their daily lives; (b) learners have some misconceptions about science, art, engineering, and invention as disciplines, but also as a field of practice, even after engaging in out-of-school science activities; and (c) learners readily connect the STEM practices in the program with perceptions of science in their daily lives.

Introduction

Learning happens across multiple places, spaces, and times (Bell, Tzou, Bricker, & Baines, 2012), enabling learners to participate in opportunities in formal settings such as schools, and across informal settings such as community clubs, online, and in public spaces (Barron & Bell, 2015; Ito et al., 2013). In STEM education, learning environments that help young people participate in out-of-school science practices are essential for encouraging individuals from nondominant populations to participate in STEM activities (e.g., Pinkard, Erete, Martin, & McKinney de Royston, 2017). These informal environments help learners position their identities in relation to STEM and develop ways to connect their everyday practices with STEM fields (e.g., Calabrese Barton et al., 2013; Pinkard et al., 2017).

Prior work demonstrates that participation in informal learning activities can afford opportunities for nondominant populations in STEM (including historically marginalized and oppressed groups) in which their perceptions about themselves and their practices are affected (e.g., Barton & Tan, 2010). For example, Pinkard et al. (2017) explored how a narrative-based STEM learning environment designed to engage young women positively affected their interest in computational activities. The young women took part in an out-of-school program that leveraged their existing interests and encouraged them to participate in STEM hands-on activities to create narrative-based digital artifacts. This enabled the young women to participate in STEM practices and reposition their identities and capabilities in relation to STEM. Similarly, in a study that investigated the development of agency in learning science among low-income students from historically marginalized ethnic and racial backgrounds, Barton and Tan's (2010) findings suggest that when activities are situated in community-based contexts, students increase their science learning agency and level of participation in community work, and begin to view themselves as capable of participating in science activities.

In this study, we build on work that addresses participation in out-of-school STEM education programs for historically marginalized and nondominant populations. Specifically, we seek to answer three questions: (a) How do learners perceive the connection between science and other disciplines? (b) How do out-of-school STEM activities help learners make connections between everyday science and school science? and (c) How does participating in these activities shape students' perceptions of scientists, artists, engineers, and inventors? The goal of the current study was to investigate the learning processes of people engaging in science and hands-on activities, specifically in a community-based program designed for the nondominant population of Arab Palestinian adolescents.

Methods

Context and Research Site

For this study, we collaborated with Al-Rowad for Science and Technology, a community-based organization situated in an Arab town in the Haifa district. Al-Rowad is led by Arab Palestinian scientists, science educators, and youth in Israel to provide access to science-education programs both in and out of schools. The organization serves historically marginalized populations from the Palestinian minority in the country. The need for these programs for Palestinian learners in Israel derives from multiple factors, including: (a) Palestinians in Israel are underrepresented in STEM fields, and this underrepresentation is reflected in the job market and higher education; (2) significant gaps in reading, math, and science literacy exist between Hebrew speakers and Arabic speakers in Israel, reflected in the most recent PISA reports of the 2018 Organization for Economic Co-operation and Development (OECD, 2019); and (c) historically, public science education within schools in this context has been shaped by dominant colonial narratives of Western science. This situation requires action from both public education and civil organizations to address these challenges and design equity-oriented learning environments that leverage the potential of Palestinian learners to engage and participate in STEM-related fields while also attending for how STEM impacts their lives.

One of Al-Rowad's programs is centered on engaging learners with high-quality, hands-on activities that go beyond the formal school science experience. The goal of these activities is to improve learners' attitudes toward STEM, help them better understand science concepts, forge connections between science and everyday life, and build an infrastructure for STEM leaders within the Arab Palestinian society in Israel. In this study, we observed four days (approximately 100 minutes each; total learning time approximately 395 minutes) of an out-of-school program in which learners completed hands-on activities that were designed, engineered, and facilitated by the organization.

Two instructors from the organization led the activities. The lead instructor facilitated discussion and guided learners through activities. This instructor has a degree in biotechnology engineering and has been part of the organization for five years. A second instructor served as an assistant and helped learners with the equipment and building during the hands-on activities. This instructor has a nursing education background and has been part of the organization for eight years.

Activities

The hands-on activities are designed to engage learners in science learning in an out-of-school environment. Each day over the course of four days, learners engaged with one activity that covered diverse topics related to science. These activities (see Figure 1) have features that demonstrate science, engineering, art, and math as interconnected disciplines that are complementary to one another. The first activity, titled SAP (Super Absorbent Polymer), focused on concepts that combine diffusion, primary colors, and observing how chemicals change through time. The instructor began with an introduction that involved discussion with students about the major concepts. Next, students received instructions to complete the activity. To do this, they used test tubes, pipettes, and wood to build an artifact. In this activity, students separated a solution of three primary colors with a white substance and then observed the diffusion process when colors begin to merge. The second activity, Newton's Disc, began with an overview of the previous day's activity to emphasize connections across activities. In the introduction, the instructor discussed concepts related to movement, primary and light colors, and gear-wheel movement. Then, students did a physics experiment in which they built a Newton disc using a laser-cut gear. The third activity centered on building an illuminated drawing board. In this activity, participants learned about phosphorescence phenomenon and applied their understanding by creating drawings on their boards. The activity began with reviewing content from the previous day. Students then viewed slides about major concepts, completed an activity with lights on the board, and then engaged in a hands-on activity to create the drawing board. On the fourth day, students did an experiment with oil and water to learn about density and then created soap. Through the four activities, the instructors engaged students in discussions and presented slides with examples of science in everyday life, such as rainbow colors, animation, volcanoes, cooking, and wheels. The two instructors also encouraged participation from all learners by assigning roles, acknowledging individuals' contributions, and assigning voluntary homework to explore further information and present it the following day with other participants.

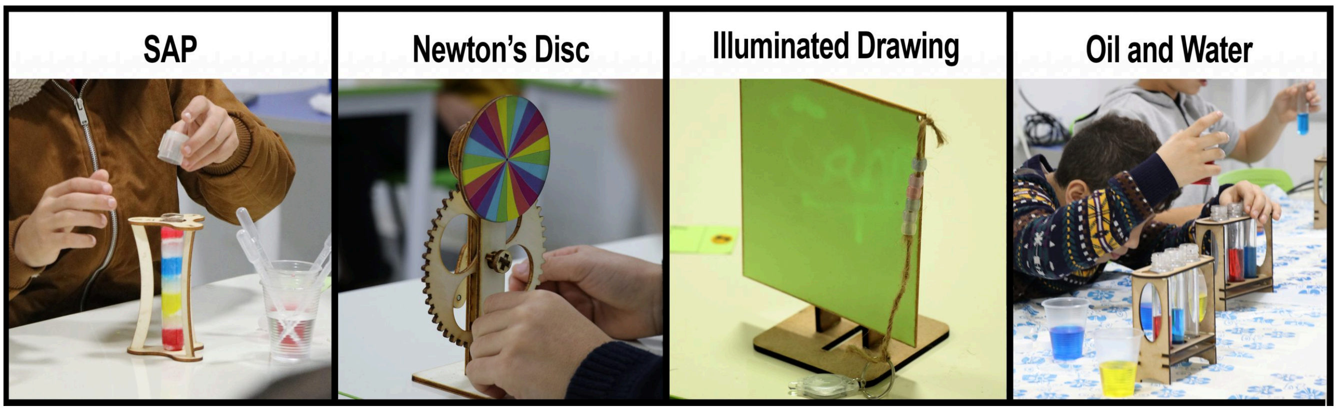

Figure 1. These are examples of final outcomes of activities artifacts.

Participants

With assistance from Al-Rowad's coordinators, we recruited 10 learners to participate in the study. The participants (five boys, five girls) were all Arabic-speaking, from five different schools, and all were students at Arab public schools in Haifa District in Israel.

Participants were currently enrolled in fifth grade (n = 5) or sixth grade (n = 5). While the students predominantly speak Arabic and it is the first language for all of them, they also learn English and Hebrew as second and third languages in school. The interviews, lecture, and instructions were all conducted in spoken Arabic; thus, this was a diglossic environment, meaning that both academic and informal Arabic was used—informal during sessions and academic when using science concepts and filling out postactivity questionnaires.

Data

We collected multiple sources of data, including observation notes, videos of activity sessions, interviews with instructors, motivation measures, postactivity reflections, and interviews with learners. In this paper, we focus on the postactivity reflections and semistructured interviews with learners.

After each day of instruction, learners completed a postactivity reflection that consisted of seven items designed to gather their perceptions of the experience, an explanation of what they learned, and examples that illustrate their explanation, either in the context of the activities or from their everyday lives. Interviews were conducted after all four days of instruction were completed. One researcher, who is fluent in Arabic, conducted the interviews. Interviews were 40–60 minutes long (average time = 48.4 minutes, *SD* = 8.9 minutes). All interviews were recorded. The interview protocol consisted of several questions that aimed at reviewing the activities and understanding students' perceptions of what they learned. In addition, we asked students about their perceptions of people in a variety of roles—scientists, artists, engineers, and inventors—in an effort to understand whether they see connections between these roles and the artifacts they created during the four days, and how they relate these roles to their daily lives. Finally, we asked questions regarding their overall STEM activities in daily life to understand whether they see a difference between informal learning and school science. To help with recall and provide context, the interviewer displayed photos of the final artifacts on a laptop screen, and learners chose which activity to discuss. On average, learners discussed 2.9 out of the four activities.

Data Analysis

We conducted an inductive initial coding process for the postactivity questionnaire and identified students' perceptions of scientists, artists, engineers, and inventors in the interviews by asking them what they think people occupying these roles do, or what they think their characteristics are. We identified students' overall STEM-related activities in daily life through notes collected during interviews. Following Saldana (2015), one member conducted two coding cycles of the postactivity questionnaires to identify major themes derived from student reflections. The data from the postactivity questionnaire were aggregated and analyzed as a whole. These reflections were also compared to and aligned with student interview responses.

Learners' Perceptions of the Activities

In this section, we describe learners' perceptions of the activities through the dominant themes derived from the coding of the postactivity questionnaires and also reflected during the interviews.

Perceptions of Science

All learners mentioned that they found the activities fun. Learners who articulated reasons for their opinions did so in multiple ways: (a) providing general examples, (b) recalling specific information discussed during the activity, and (c) describing specific characteristics of the final artifact. Specifically, learners made statements such as "it was fun" (n = 4) without explanation, or "I liked the outcomes and results" and "working hard to get results" (n = 2), or general statements such as "I learned new things" (n = 2). Examples of specific information students provided include "we learned about volcanoes," "I learned that oil and water do not interact or mix," "Newton's Disc move," and "I saw how animals could see." Finally, learners provided descriptions of the activity characteristics: The activity is beautiful and nice (n = 5); it looks nice and has nice colors, compositions, and changes its colors (n = 3); it has a nice structure for the model (n = 2); it involves a hands-on experience (n = 2); and it is magical (n = 1). When asked during interviews, students operationalized "beautiful" and "nice" in multiple ways: aesthetic, useful, beneficial and respectful to others, and well designed. Similarly, when students were prompted to describe whether *science* (in general) is fun, their answers were all positive.

When learners were prompted to compare the activities they completed in this program with their school science classes, they described that "there are not as much hands-on activities, fun, and experiments [at school]." Learners framed school science as "writing, reading, using textbooks, and doing assignments." Learners described this program's activities as fun and entertaining because of the friendly environment and friends they could make in the program, while describing school science as boring (n = 7) and requiring more reading and writing compared to the workshop (n = 6). Learners also provided examples of how the science they are learning in the program is beneficial and useful (n = 3) as it helps them "solve problems" and "connects to daily life." They also described the program activities once again as "beautiful and nice" (n = 3), and they recalled specific information from slides and instructions presented during the sessions as beneficial (n = 3).

When asked what they learned, they often recalled lecture or discussion material rather than knowledge acquired during the hands-on part of the activity, suggesting that they viewed the hands-on part as "fun" and the more didactic part as "learning." For example, learners provided information such as "I learned about primary colors" and "oil and water do not mix" (n = 9), or they mentioned procedures they learned (n = 2) such as "I learned how the eye works" without describing it, or they made general statements such as "I learned a lot," "it is magical," and "fun" (n = 4). Other students mentioned that they learned information that was useful for their daily lives (n = 3). During the interviews, learners particularly appreciated that the environment was friendly, that the instructors engaged everyone in the discussion, and that "everyone was able to participate" respectfully.

When learners were prompted to describe how they like doing science activities, their responses were consistent with previous items. All learners viewed science positively, except for one student who did view it positively in the postactivity questionnaire but not during the interview. This student described science activities she did as fun; however, she insisted that science in general and school science are not. Learners mentioned that they like science because it is fun and entertaining (n = 8), made general yet positive statements (e.g., "I like it a lot"; n = 4), recalled specific information from activities they did (n = 3), expressed that they enjoyed the hands-on part of science (n = 3), mentioned that science is beautiful (n = 3) and that it is useful and beneficial (n = 2), shared that they liked that they produced a take-home product (n = 2), and said science cultivates intelligence and curiosity (n = 2). When learners were asked whether they specifically liked the science activities they just completed, they mentioned qualities of the activity (useful, beautiful, has suspense, magical, smart, changes in shape; n = 6), and, once again, provided specific examples of an observation during activities ("fun because of the sparkling substance," "I learned about lava," "it lights up"; n = 4). They described the activities in terms of novelty (n = 4) by mentioning general statements such as "new activities," "different type of activities," "did not see it before," "it taught me new things," and other statements such as "wonderful" (n = 2), "they did activities in front of us" and "we could take it home" (n = 2), and "it taught me new things."

Hands-On Activities in Relation to Science, Art, Engineering, and Invention

During the interview, we asked students which discipline was practiced as they completed the activities (science, art, engineering, or invention) or whether they felt like a scientist, artist, engineer, or inventor when doing the activities. Learners' answers were mixed, even though all of the activities were framed by the instructors as science experiments with interdisciplinary features. For the scope of this paper, we provide two specific examples, one for a learner who talked about all four activities in the interview, and another who talked about three activities in the interview. In Table 1, we provide a high-level description that synthesizes learners' responses of roles and qualities of scientists, artists, inventors, and engineers during the interviews.

The first student said that the SAP activity felt like an art project because of the colors. According to the learner, when doing this activity, she felt like an *artist*. When prompted to describe what an artist does, the student said, "He plans, thinks about the premise of what will happen in colors, and has a hypothesis about it," and mentioned that she does that when she draws. When prompted to describe artists, she said, “An artist is smart, focuses, knows what he or she wants, benefits the world, improves and develops solutions, discovers, hypotheses, and [is] diligent.” Likely, she was trying to relate the artist qualities to activities she engages in as someone who likes art and drawing. When she described the oil and water activity, the student described it as a scientific experiment since it involved laboratory equipment such as test tubes and pipettes, and because there was a reaction when citric acid was added. When prompted to describe what a scientist does, she said, “He knows, builds, makes inventions, develops, innovates, does experiments, tries over and over again like Thomas Edison.” When the learner described the illuminated drawing activity, she said that she felt like an artist because the activity involved drawing on a phosphorous board. She provided examples of how she does this when she draws. Finally, when discussing the Newton’s Disc activity, the learner described it as encompassing multiple roles: an artist since it involves colors, a scientist since she discovered something new, an inventor since she was inventing something for herself, and an engineer since she managed to build everything correctly. When prompted to describe an inventor, she said, “He endures risk and fatigue and strives,” and when prompted to describe engineers she said, “Smart, bear challenges, and ask others to know their needs.”

The second learner described the SAP activity as an art activity because of the colors and learning about colors. The learner described an artist as someone who draws and plans. When describing the oil and water activity he referred to it as a science experiment, since it involves a chemical reaction. When prompted to describe what a scientist does, he said, “A scientist is intelligent, has a lot of knowledge, he has patience, and ethics, meaning he reasons about outcomes and consequences.” When asked about Newton’s Disc, the learner mentioned he felt like an engineer and inventor doing this activity, because “it involved installation and steps, stages, and discovery.”

Overall, student perceptions for roles of scientists, artists, inventors, and engineers were diverse. Some of these perceptions indicate an incomplete image about the roles and reflects how learners connect these roles to their daily lives in two ways: (a) traits they themselves have and (b) traits they think these professions have, based on things around them in daily life or normative views of STEM. For example, one participant described that she likes drawing a lot; when she described artists, she described their activity in relation to her own practices of art: “When the artist tries and experiments with things, if something does not work the artist tries it again. For example, when I want to draw little things I need to be patient and have the ability to fix it instead of damaging my drawing.” The same learner referred to engineering as a matter of “constructing engineering,” a theme that was dominant among all learners: associating engineering with building, designing and constructing buildings and physical infrastructure. Specifically, when asked about the characteristics of engineers she said, “I think … [my dad who is an engineer] loves building, treats people respectfully, engineers in a right way, meaning builds things that cause no harm or damage to people, has trust and honesty.”

	Examples of Activities
Scientists	Scientists have patience and persistence, are smart, ethical, and socially responsible, and work alone.
Artists	Artists draw and paint, use imagination to plan and implement drawings, think and plan what they want, care about aesthetics, and have patience and persistence to experiment with things like colors and drawings.
Inventors	Inventors are smart and have patience. They need to be accurate in terms of mastery and focus, they have ideas and imagination, they experiment and try, and they build things and have equipment to do that.
Engineers	Engineers build things like buildings, they think about the pros and cons of things they build, they have to be accurate so they do not cause damage, they work with people, they plan things, do high- quality work, draw things on paper, and use imagination. Engineering is like geometry.

Table 1. Examples of perceptions for roles of scientists, artists, inventors, and engineers derived from learners' answers.

Discussion and Implications

As described earlier, all learners reported that they enjoyed the four activities. This was reflected in the postactivity questionnaires and also during the interviews. They also reported that the activities made them perceive science as fun. Incorporating fun, joy, and play was an essential component in supporting learners and helping them to connect to the program activities. Fun, joy, and play create learning opportunities that provide multiple modes of participation (e.g., planning, building, joining discussions, asking questions) (Gee 2017; Resnick, 2018). This allows students to participate in the activities and also helps learners perceive that doing science also could be a social activity.

At the same time, not all learners perceived these activities as science activities, with some describing them as "art only." This could stem from these activities being quite different from their school science activities—participants may have had difficulty connecting STEM practices with the science facts and phenomena often taught in school. Although learners described the scientific process used to create the artifacts, some learners viewed the final outcome as art. Many learners reported that these activities were very different from their school science experiences because they did not include "writing and reading." This study suggests that there is a need to help learners make deeper connections between school science and out-of-school STEM programs and to help students expand the way they conceptualize science (e.g., Barton & Tan, 2010; Calabrese Barton et al., 2013).

When describing the qualities and roles of scientists, artists, inventors, and engineers, as well as the artifacts, students often used examples related to their personal traits (e.g., smart, patient, ethical), activities they often do at home or at school (e.g., drawing), or normative views of scientists, inventors, engineers (e.g., have a hypothesis). They often described incomplete images of a certain discipline (e.g., viewing art as drawing or coloring, describing engineering as building houses). Expanding learners' perspectives on what these disciplines offer and how they intersect can be beneficial to help them draw connections between multiple fields and explore STEM practices beyond normative definitions or school science. Expanding perspectives can offer pathways for interdisciplinary STEM learning in which nondominant learners can see themselves as actively engaged in understanding STEM and its relevance to their everyday lives (e.g., Barton & Tan, 2010; Tzou, Scalone, & Bell, 2010; Vossoughi, Escudé, Kong, & Hooper, 2013).

Finally, learners' descriptions of artifacts reflect that their sense making around the term *beautiful* has multiple meanings: aesthetic, useful, beneficial and respectful to others, and well designed, reflecting that the learners were trying to label these artifacts with qualities they consider to be positive as they complete their work or projects. These qualities were also consistent with some learners' articulations about ethics. These responses create an opportunity for researchers and educators to understand the societally and ethically expansive ways that these learners are thinking about the act of creation as they learn (Bang & Vossoughi, 2016).

Despite the small sample size, we believe this study sheds light on how community-based efforts could leverage and support STEM learning among learners from nondominant populations. In future work, taking into consideration heterogeneity among learners (e.g., Rosebery, Ogonowski, DiSchino, & Warren, 2010) may help in understanding the diverse epistemologies and ways of knowing reflected by participants from this nondominant population, which might be more or less profoundly affected by the social, economic, and political situation, and systematic oppression. While these results show promising outcomes, suggesting that this type of environment could help learners participate in and benefit from hands-on science activities, future work should investigate in-depth the learners' cognitive engagement when doing these activities. It should also examine how connections made by learners between these activities and their everyday lives can transfer and expand beyond the scope of the program.

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