Examining Students' Perceptions of Equity in Informal STEM Education: A Community-Engaged, Visual Method

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Abstract This report from the field presents a community-engaged, visual method for evaluating students' perceptions of equity in Maker Club, an informal STEM (Science, Technology, Math, and Engineering) education program in Ohio. The purpose of the program is to increase access to and interest in STEM fields among underserved communities. A total of fifteen middle school-aged program participants from two cohorts that were hosted at two different after-school program sites engaged in participant-employed photography to document their views of the implementation of six design principles for equitable learning. The evaluation process unfolded in five phases: 1) recruitment of co-researchers, including explanation of guidelines; 2) teaching co-researchers how to use the camera, including testing out the camera; 3) co-researchers observing, and taking pictures of, students and staff engaged in the makerspace; 4) informal photo interviewing; 5) sharing with program staff via informal conversations and a formal meeting discussion. Takeaways include that co-researchers perceived students benefiting from social support, community partner presence, and local knowledge being recognized. Lessons learned entail keeping students on track, ensuring that there is enough staff support focused on the evaluation process, and being open to other potential, meaningful uses of co-researchers' photos.

KeyWords informal STEM education, visual methods, photography, evaluation, equity

As informal STEM (Science, Technology, Math, and Engineering) education institutions design and implement outreach programs in community settings to increase access to and equity in STEM fields, assessments that center historically marginalized perspectives become key to promoting equitable and inclusive learning (Garibay & Teasdale, 2019). Traditional survey techniques are supported by desire to generate "objective" results that privilege researcher expertise (Delanty, 1997), which often reproduce the same power dynamics that community-based programs aim to overcome (Chouinard & Cousins, 2015). Even subjective strategies, such as in-depth interviews, can sustain a dualistic standpoint that fails to take into account socially constructed norms, logics, and values (Berger and Luckmann, 1966) that structure informal STEM "counter-spaces" (Solorzano, Ceja, & Yosso, 2000, p. 70). However, participatory approaches that provide opportunities for local involvement throughout the research enterprise can help to overcome the shortcomings of conventional strategies (Godderis & Root, 2023; Neapetung, Bradford, & Bharadwaj, 2019). Intersubjective and participatory

evaluations, for example, allow for non-dominant voices to guide discursive and collective meaning-making processes (Garibay & Teasdale, 2019).

The underrepresentation of communities of color and women in STEM careers (U.S. Bureau of Labor Statistics, 2023) motivated a regional science center in Ohio to expand and democratize their educational initiatives in local STEM deserts by transforming after-school sites into makerspaces that give underserved, young people access to project-based design and fabrication activities. Specifically called "Maker Club," the program consists of twelve hands-on learning sessions that provide students with opportunities to engage with a variety of STEM tools and devices such as laser cutters, computer programs, 3D printers, and circuits. Objectives are to foster the development of students' identities as makers and their interests in STEM fields.

This report from the field illustrates the use of a community-engaged, visual evaluation method to examine students' perceptions of equity in Maker Club. The purpose of this approach was to gain insight into whether and, if so, how program participants perceived the makerspace as an equitable learning environment. The significance of this strategy was that its use provided the science center staff with a community-created and bottom-up, rather than a top-down (Fisher et al., 2023), view of equity in Maker Club. As a result, the program could be enhanced according to a locally grounded perspective.

Evaluation Tool and Process Description

Visual methods are well-documented in community-engaged (Mitchell et al., 2017) and educational research (Miles & Howes, 2014). Photovoice (Wang, 2006), participatory photo mapping (Teixeira & Gardner, 2017), and photo novellas (Wang & Burris, 1994) are a few of the specific approaches that use photography to explore youth's perceptions and experiences as well as to promote empowerment. Community-engaged research has employed participatory photography to examine youth's views on a wide range of topics such as service delivery (Savuro et al., 2021), property vacancy (Teixeira, 2015), and substance abuse assessment and prevention initiatives (Brazg et al., 2011). In participatory research with a focus on education, studies have investigated the connection between schooling and girls' empowerment in India (Shah, 2015), the social inclusion of students with disabilities in schools in Indonesia (Bonati & Andriana, 2021), and the persistence of minoritized students in engineering education (Herrera et al., 2023). Past research shows that participatory photography is particularly effective in co-generating knowledge with marginalized youth (Capous-Desyllas, Mountz, & Pestine-Stevens, 2019).

This project used "participant-employed photography" (Castleden, et al., 2008, p. 1395), whereby participants took pictures of subjects of their choosing. The first author then referred to these images to elicit the photographers' reflections, perspectives, and narratives (Hurworth, 2003). Photos help to bridge cultural and social divides between researchers and participants (Carlsson, 2001) as they become co-researchers in this co-learning process (Israel et al., 1998).

The evaluation tool consisted of a worksheet-type document with seven prompts intended to guide the students in taking pictures and facilitate an understanding of how they perceive equity in an informal STEM education program. The first author wrote the prompts in plain

language based on six design principles for equitable learning, which are research-informed and interrelated and, when applied together, make up a "holistic framework" (Bang et al., 2021, p.1). Below are the prompts and accompanying design principles:

1. Take a picture that shows people having fun together.
   (Design Principle 1: Center Relationships)
2. Take a picture of people learning together.
   (Design Principle 1: Center Relationships)
3. Take a picture of something in the activity that makes you feel happy.
   (Design Principle 2: Create a Culture of Affirmation and Belonging)
4. Take a picture of something that reflects an interest of yours.
   (Design Principle 3: Build from Students' Interests and Take a Whole Child Approach to Their Development)
5. Take a picture of something in the activity that is familiar to you or something you already know how to do.
   (Design Principle 4: Engage Students' and Families' Knowledge in Disciplinary Learning)
6. Take a picture of someone making something creative.
   (Design Principle 5: Provide Creative, Inquiry-Based Forms of Learning)
7. Take a picture of a team member interacting positively with others.
   (Design Principle 6: Address Educator Needs and Learning)

At the outset, the first author asked potential co-researchers if they wanted to do a "photo challenge" that would entail them taking pictures of what they were seeing during the activities that represented the prompts. She explained that their work would help program staff understand how they view the activities and offered candy upon completion as an incentive. Being able to use the cameras also served as a motivating factor. The first author presented this evaluative research opportunity to students after they finished their projects, or if they were not interested in doing the activity of the day, in order to keep students invested in the makerspace. She also made sure that students understood that their participation was completely voluntary.

Once students agreed to participate, the first author explained the importance of getting permission to take someone's photo. Then they were each provided with a point-and-shoot digital camera and instructions on how to use it, because the majority of students had never used one before. Therefore, this experience was an opportunity for participants to learn new technology, which fit nicely with the objectives of the program.

After students completed the "photo challenge," the first author engaged them in informal photo-elicitation interviews (Hurworth, 2003). Specifically, she asked them to identify each photo that they took and explain the why the corresponding prompt inspired the photo. She accomplished this task by manually going through the photos through the camera viewer and having conversations about the pictures that they took and why they took them (Carlsson, 2001). When there was not enough time to go through each camera the same day that pictures were taken, the first author was able to go through printed photos that program staff brought

with them the next time. As they intersubjectively discussed the photos in relation to the prompts, the first author took notes of the photos that they identified and the photographers' reasonings for why they took each photo. The next section describes the first author's observations and photo themes.

Observations and Themes

The assessment was carried out in collaboration with fifteen middle school-aged program participants from two cohorts that were hosted at two different program sites. The evaluation process unfolded in five phases: 1) recruitment of co-researchers, including explanation of guidelines; 2) teaching co-researchers how to use the camera, including testing out the camera; 3) co-researchers observing, and taking pictures of, students and staff engaged in the makerspace; 4) informal photo interviewing; and 5) sharing with program staff via informal conversations and a formal meeting discussion.

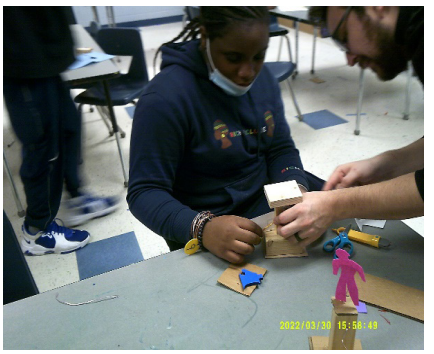

Figure 1. Photo of student and staff member working on crank puppet activity. Taken to show people having fun together. (Photo taken by student co-researcher)

As the co-researchers worked through the prompts, the first author checked in with them periodically to ask about their progress and answer any questions that they had. The co-researchers grasped the prompts well and seemed genuinely interested in and excited about using the cameras. They also appeared to have fun when taking pictures of their peers as they worked on their projects and while taking "selfies" when the prompts inspired them to do so. The co-researchers' photos, guided by their understandings of the prompts that were based on the design principles for an equitable learning environment, represented how students gave meaning to and valued equity in the informal STEM education program, in which they were participants.

Regarding depiction of the first principle, "center relationships," there were two common types of images in response to the first prompt about people having fun together. One set of photos mostly showed students working alongside one another and diligently engaging with the tools and materials. The other set showed students socializing by dancing, hanging out, and posing for one another by making hand gestures like the peace sign. In other words, they were not participating in the planned activity of the day in the moment that the pictures were taken, but they were socially partaking in the educational environment that the program provided. Images that represented the second prompt about people learning together

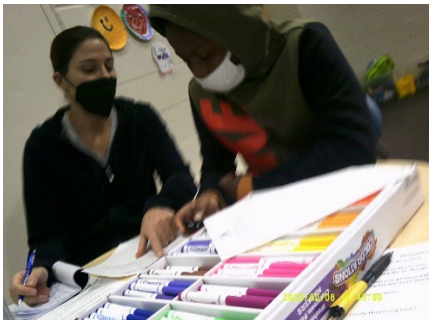

Figure 2. Photo of student co-researcher's little brother working on a project with the first author. Taken because seeing his brother working made him happy. (Photo taken by student co-researcher)

collectively depicted students looking down at their projects in a focused manner, often with either a program staff or peer visually showing how to take a next step in the project design process (see Figure 1).

The second design principle, "create a culture of affirmation and belonging," was represented by photos that captured something in the activity that made the co-researcher feel happy. The images reflected mostly people who were meaningful to the photographer, engaging in positive ways, and/or expressing joy. For example, several pictures included siblings. One co-researcher pointed out proudly that his picture is of his little brother working (see Figure 2). Another co-researcher took a picture of himself with one of the community partner coordinators. He explained that he was sad that this person was leaving his position with the organization but happy for their friendship. A different co-researcher took a picture of his peer using a glue gun and said, "It makes me feel happy because she's happy."

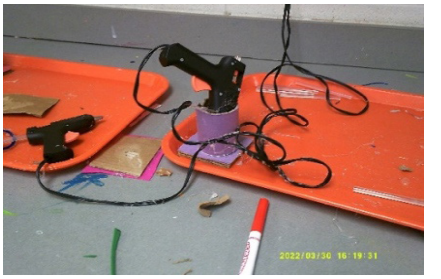

Figure 3. Photo of glue guns. Taken to illustrate students' interests and familiarities. (Photo taken by student co-researcher)

There were commonalities across images that represented design principles three, "build from students' interests and take a whole child approach to their development," and four, "engage students' and families' knowledge in disciplinary learning." This overlap between students' interests and familiarities is not surprising. Many of the pictures portrayed materials and tools, including crayons, markers, drills, and glue guns. Drawing was a popular know-how. In fact, one student attempted twice to take a picture of a whiteboard that was used to plan out designs, but her picture kept turning out blurry. Then she resorted to taking a picture of the palm of her hand, on which she wrote the word "draw," with a heart underneath. A different co-researcher took a picture of a fish design made out of wire because he likes art. Another took a picture of a peer working with a science center staff member on a circuit activity. The co-researcher explained that he was unable to get his circuit to function during the last session, and he noted that he was interested in learning how to get it to work. Several students highlighted the glue gun and mentioned that they have one at home or have used one before.

Figure 4. Photo of students working on their wire designs. Taken to reflect something creative. (Photo taken by student co-researcher)

Co-researchers were also prompted to take a picture of something creative, in order to represent design principle five, "provide creative, inquiry-based forms of learning." Pictures were primarily of finished products or focused on the hands-on aspect of making. A co-researcher smiled about his picture of his wire design of a green pepper, while another one was happy

about a picture that he took of his brother using a cardboard cutter. Other pictures showed students bending wires, using glue guns, and drawing their designs on whiteboards (Figure 3).

Figure 5. Photo of staff member stabilizing drill for student. Taken to represent team members interacting positively with others. (Photo taken by student co-researcher).

The last set of photos was of team members interacting positively with others and represented design principle six, "address educator needs and learning." These images mostly illustrated staff from the science center and the community organization helping students with their projects in a hands-on way. For example, pictures included staff members stabilizing a drill for a student and holding down a puppet project so that the student could push a wire through it (See Figure 5). Other pictures were of staff making silly faces for the camera.

Conclusion

In terms of understanding equity from this participant-employed photography evaluation method, there were four main takeaways. The first was that the co-researchers clearly perceived students benefiting from social support and engagement through the program activities. The second takeaway was the importance of the presence of staff from the community partner organizations during the activities. The images corroborated that site staff involvement was crucial for students to feel affirmed because they often wanted to show staff their projects and receive positive feedback. The third takeaway was that pictures that reveal elements of students' previous knowledge may help to reveal power relationships that influence local understandings (Barton & Tan, 2018) and overcome biases that might shape educational approaches and interactions with the program participants. For example, assumptions could be made that participants, given their low socioeconomic status, likely do not have access to some of the learning tools. In this case, what became apparent quickly was that some participants had not only experienced using a few of the tools, such as glue guns, before but also had them at home. And the fourth takeaway was that images that did not necessarily fit among the common themes still provided important equity-based insight. For instance, one co-researcher took a picture of a Pop Tart wrapper. She explained that she likes Pop Tarts and the fact that she gets to eat during the activities. This unique picture is reflective of the need to take a "whole child approach," which is an aspect of design principle three. Specifically, it shows the importance of meeting students' basic needs to promote participation.

Important were the lessons learned that stemmed from reflections with program staff. One of those lessons was that there were times when participants needed to be reminded about the purpose of the evaluation and ethics of picture taking, although, in general, students stayed on task and took the activity seriously. Even when they seemed to "stray" from the prompts, the first author hesitated to redirect them. In these moments, instead, she considered them to be experimenting with the technology and exploring their experiences in creative ways. Only during the few occasions when some students seemed to distract their peers did she encourage them to refocus by simply asking them which prompt they were working on. A second lesson

was that program staff had little time to support the evaluation. Therefore, depending on the size of the group and number of staff, what would help would be designating a staff member to focus solely on this activity. A third lesson includes being open to the potential to use the photos in other ways to enrich the program. For example, staff wanted to incorporate this activity with future cohorts and post their photos on a community board at the program site, in order to promote the program and the work that students were doing.

The authors consider that this visual method is valuable for generating participants' interest in assessment activities and, as a result, promotes their involvement in program evaluation. Using such an accessible and participatory strategy allows for participants' perspectives to guide understandings of equity. Ultimately, this type of visual, community-based research has the potential to elevate non-dominant views in informal STEM education and lead to the creation of more culturally responsive programs.

Regarding possibilities for future use of this evaluation method, the authors noted that one opportunity that was not fully explored during the Maker Club sessions was the potential to utilize the photos captured to conduct formative assessment of student understanding about tool use or the underlying scientific concepts or skills identified as learning outcomes by the program staff. Therefore, an additional aspect of design principle four might focus more specifically on the students' development of understanding, in addition to the previous knowledge that they bring into the space. The prompt could then be tailored to the activity and the underlying concepts that the staff aim to address in that session or series of sessions. Such an approach has the potential to lead to "intellectual inclusion" (Vossoughi et al., 2013). Example prompts could be, "Take a picture of the most interesting feature of the coding program," or, "Take a picture that visually explains how a circuit works." Then, when students have the opportunity to share thoughts during informal photo interviewing, the researcher could prompt the students to explain the concept using the images. This strategy serves as a formative assessment, which, in makerspaces, encourages participants to discuss the content that they are learning throughout the making process (Tan et al., 2018). More specifically, formative assessment provides the opportunity for the program staff to identify areas that might be challenging for students and address them more thoroughly or, conversely, to determine concepts that come easily for students and need less investment of time in explanation.

Another opportunity involves students looking holistically at the outcomes of their documentation by reviewing their images and making recommendations for future program delivery. To get their critical feedback, prompts could say, "Take a photo of an aspect of the program that you would like to improve," or, "Take a photo of something you wish had happened more often." These photos and the subsequent individual interviews could be utilized as stand-alone examples of student advocacy. To foster collective advocacy that is more aligned with photovoice initiatives (Wang, 2006), this same activity could be done in a group format. In these ways, the authors feel that the tool could be maximized to promote equity.

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