Chapter # 11

"YOU CAN BRING YOURSELF INTO YOUR PIECE." YOUNG WOMEN'S AGENCY IN MAKING

Ken Rafanan, Nuria Jaumot-Pascual, Elise Levin-Güracar, & Teresa Lara-Meloy
TERC, Inc., USA

ABSTRACT
While many makerspaces are created by and cater to middle-aged males, our research has found that young women enjoy engaging in a multitude of making disciplines, including those traditionally thought of as masculine such as woodworking. In the AAMASE project, we worked with participants and program staff to co-design an eight-week program focusing on introducing several making disciplines with a set of principles, activities, and tools to support youths' agency in a community-based makerspace in the mid-Atlantic region of the United States. Most participants were African American high-school-aged young women from two out-of-school learning organizations and a private school. Making projects ranged from single-day projects, such as creating resin art pieces, to longer multi-session projects, such as making a laser engraved cutting board. We found that projects supported participants' agency as assessed through a framework we developed consisting of five criteria (self-efficacy, personalization, connection, planfulness, and iteration) consistent with the research literature on agency. Our research found that single-day projects supported participants' self-efficacy, personalization, and connection, and longer final projects supported their planfulness and iteration. The paper also briefly describes the researchers' use of artifact elicitation and provides recommendations for future research on agency and for practices that support agency.

Keywords: making, STEM, youth development, agency, design principles.

1. INTRODUCTION

African American Young Women in Making to Engage in STEM and Entrepreneurship (AAMASE) was an NSF ITEST Developing and Testing Innovations project aimed at serving 13–18-year-old young women in Greensboro, North Carolina, USA from 2022-2025. The project was a collaboration between TERC, a STEM education research and development organization, and the Forge Greensboro, a nonprofit community makerspace. Through participatory design research (PDR; Coenraad et al., 2019), AAMASE engaged youth in making and entrepreneurship activities emphasizing STEM disciplinary practices to amplify their agency while building their engagement and skills in STEM and their awareness of STEM career pathways. Youth participants learned how to design, build, and pitch a product with guidance from adult designers, makers, and entrepreneurs. Activities were designed based on the youth's interests with the goal of supporting their agency development. Activities included short, one-session projects to explore specific making disciplines and final projects where youth chose one of the making disciplines to develop a product that would address a problem from a pre-selected set of profiles, each with a design challenge that could be solved by youth in an open-ended way. For example, one of the profiles was about a young woman who needed a system to organize her school locker. AAMASE participants who chose this profile then selected one of the making disciplines they learned

earlier in the program to address the design challenge. The research included multiple data collection methods (e.g., surveys, interviews with partners and program staff, observations, artifact elicitation) to gain a holistic understanding of the PDR process from the perspective of all involved as well as the learning and changes that participating youth experienced. This paper focuses on youths' agency and experience throughout the program, integrating data from artifact elicitation interviews and observations.

2. LITERATURE REVIEW

2.1. Makerspaces as STEM Learning and Agency Developing Environments

Research has shown that makerspaces are often not supportive environments for non-dominant youth or women (Calabrese Barton & Tan, 2018). AAMASE aimed to address this challenge by situating its approach to making as a community-centered, culturally embedded practice. Making and design projects bring together tools and communities to provide both motivation and a context for developing STEM practices (Gravel et al., 2018; Martin, 2015) that are aligned with the Next Generation Science Standards (NGSS) (NGSS Lead States, 2013). We see NGSS practices and concepts (e.g., defining problems, designing solutions, patterns, cause and effect) as highly aligned with making practices when STEM content becomes part of the making. In fact, programs like AAMASE can support improved agency in implementing making practices and STEM content that results in new visions of STEM that invite broader participation (Calabrese Barton, Tan, & Greenberg, 2017).

In the making and makerspaces literature, different types of agency are described, such as individual agency, collective agency, and transformative agency. Schouweiler & Heredia (2021) defined individual agency as "the ability for youth to make meaningful decisions in how they engage with a learning setting" (p. 1). Marsh and colleagues (2018) found that implementation of a project focused on maker literacies and citizenship fostered collective agency, which often led to a strong sense of social inclusion and the development of communal cultures to address community issues. Kajamaa and Kumpulainen (2019) defined transformative agency "as a cognitive transformation and reframing process evidenced in young people's initiative and commitment to transform the context(s) of their activity for personal, academic, working life, and/or civic ends" (p. 266). Though they describe different types of agency, these three definitions converge on autonomous decision making, addressing issues of interest (individual or communal), and engaging in transformation. At the same time, the literature lacks a structured understanding of the different components of agency or how to measure it with participants in makerspaces.

2.2. Young African American Women as Makers and Entrepreneurs

Makerspaces have the potential of responding to young women's interests to build on their strengths, like overcoming obstacles and seizing opportunities (Stevens, 2002). Creating more supportive environments for making and learning requires "learning designers to consider who a maker is (and who can be a maker); what a maker does; for whom a maker makes … [and] who a maker can become in, and through, the act of making" (Castek et al., 2019, p. 5). Importantly, design principles for fostering more equitable making environments call for incorporating STEM practices as a meaningful part of the making activity (Vossoughi et al., 2013). Research into entrepreneurship education has shown that learner agency can be supported by increasing self-efficacy, perceived behavioral control, and intentional action, particularly through experiential, action-oriented pedagogies that require learners to set goals, make consequential decisions, and adapt under uncertainty (Fayolle & Gailly, 2015;

Martin, McNally, & Kay, 2013; Nabi et al., 2017). Some research, however, has suggested that entrepreneurship education outcomes can differ by gender (J. Weiss et al., 2023). To better support young women, AAMASE centered their making interests and experiences to subvert the inequities often found in making culture and actualized culturally sustaining and youth-centered pedagogy by amplifying participants' voices (Champion et al., 2020).

2.3. Engaging Young African American Women through PDR

Too often, while non-dominant youth are the intended audience for STEM programs, they are denied influence on the programs' designs. In fact, youth more broadly aren't often considered stakeholders of programs for which they are the targeted audience. For example, the design principles in Kennedy and Odell's (2014) overview of high-quality STEM programs left youth out of the stakeholders included in the design of such programs. Ignoring youth results in missed opportunities for helping minoritized youth learn STEM practices in a way that influences their views of their STEM futures (Tan et al., 2013). PDR offers an alternative: "Participatory design is an essential design strategy for creating artifacts and experiences that reflect the voices of the population being designed for and with" (Coenraad et al., 2019, p. 185). In AAMASE, three factors contributed to the program reflecting the youths' STEM and making-related interests: (1) youth were told at the beginning of the program that it was a research project and that their voices were essential for the field to learn from their experiences; (2) the AAMASE program staff and design researchers asked the participants (a majority of whom were young women of color) what they wanted to create and learn and then observed participants' engagement throughout up through reflections on completed build cycles; and (3) perhaps most critically, when youth asked for different resources or learnings, program facilitators worked diligently to provide the experience that the youth were seeking. Youths' involvement in the PDR process supported the development of their agency as a group because they experienced a program where their experiences, opinions, and interests were centered and meaningfully attended to.

3. THEORETICAL FRAMEWORK

This work is framed by a values-based theory of change centered around agency. Theory of change (C. Weiss, 1995) is a theory of how and why an initiative works. It makes clear what assumptions are being made in an intervention, and the desired outcomes. A values-based theory of change starts with a value or values for learning and engagement (Wardrip, Evancho, & McNamara, 2018). For this project, agency was a central value. We propose a definition of agency as follows: a person's or group's ability, inclination, and sensitivity to conceptualize and pursue the making of an object (physical, psychological, and/or social) to address a need or desire given a set of appropriate physical and/or social resources. This working definition allows the scaling of our unit of analysis between individual and group as appropriate as well as recognizing the salient resource features of an environment. In their review of the agency literature, Cavazzoni, Fiorini, & Veronese (2022) defined agency loosely as "people's ability to exert control over one's life and [to] pursue goals" (p. 1126) and found that studies used agency along two main conceptual pathways: (1) how an individual engages in agentic actions across their social environments; and (2) how an individual engages in agentic action in a more constrained realm of action. Our working definition of agency is aligned with the more constrained perspective as we aim to support and develop agency in participants in making and STEAM-focused learning environments.

Cavazzoni and colleagues wrote, "There is still little agreement on how this construct [of agency] should be understood and defined. ... Indeed, no current consensus or standardized methodology exists to assess agency" (2022, p. 1125). So, even though there are several validated instruments to measure agency or similar constructs, each one measures different dimensions of the phenomenon. Given this lack of consensus and based on the agency literature and Cavazzoni and colleagues' literature review, the AAMASE team proposes the following five-criteria framework for assessing agency among non-dominant youth in a makerspace. The purpose of this five-criteria framework is to translate the current research on agency that has been conducted outside of makerspaces to make it applicable to the specific conditions of makerspaces and non-dominant youth:

(1) Self-efficacy. There is evidence that participants perceive that their effort influences their success (Bandura et al., 2001). This criterion incorporates elements of perceived competence, responsibility, confidence, and an internal locus of control (i.e., participants believe that they are in charge of their own successes and failures).
(2) Personalization. The products/processes that participants create/articulate show attempts to make them more relevant or useful to specific people in participants' lives. This criterion incorporates elements of freedom, autonomy, and voice. The notion of personalization here aligns with "voice" and "decision-making" addressed by Zimmerman and colleagues (2019) related to participants' ability to articulate choices and opinions without the need to seek outside approval.
(3) Connection. The products/processes that participants create/articulate show connections to and empathy for self and/or others. This criterion incorporates elements of participation in a community, such as through service, and critical consciousness. These elements are related to Bentley-Edwards' (2016) work on racial agency, which engages notions of group cohesion and the sense of being able to enact change in the world.
(4) Planfulness. The products/processes that participants create/articulate show evidence that they were pursued based on some plan or design. This criterion incorporates elements of fact gathering and problem solving (Hitlin & Elder, 2006) in decision-making processes.
(5) Iteration. The products/processes that participants create/articulate show evidence that they were improved upon. This criterion incorporates elements of resilience (Lautamo et al., 2020) and the flexibility to adapt in the face of difficulties or changes.

We developed these five criteria for assessing agency focused on non-dominant youth in makerspaces; so, they are not meant to be exhaustive or applicable to all educational settings or all youth. We based the selection of these criteria on being immersed in the data collected as part of our research in making and makerspaces in this project, which allowed us to identify the most salient due to their strong alignment with the PDR framework we employed in the design and implementation of the project. In addition, these build on our previous work on identity development through making (Knudsen, Jaumot-Pascual & Levin Güracar, 2025).

4. RESEARCH DESIGN AND METHODS

4.1. Research Design

AAMASE conducted PDR (Coenraad et al., 2019) where curriculum was designed, tested, and modified with the population for which it was being designed in an iterative

process where the research data informed curriculum development. The research used a mixed methods design (Creswell, 2021) that included surveys, artifact elicitation interviews with youth, interviews with facilitators, session recordings and observations, and document analysis. The purpose of this mixed methods design was to get a broad view of how the program worked for the youth and others involved, to understand youths' experiences in the program and what they learned, and to learn how the PDR process worked for all involved. The multiple data collection methods were designed to provide information about the study's phenomena from multiple perspectives to allow for triangulation of findings (Greene, 2007).

4.2. Data Collection Methods

A major element of data collection was artifact elicitation (Douglas et al., 2015; Levin-Güracar et al., 2024), wherein the interviewee brings an artifact that they made in the program with them into the interview to spark a conversation about their experiences and what they learned. Since the objects were created by the youth, they embody their knowledge, skills, and attitudes and make interviews easier by shifting the focus from the interviewer-interviewee dyad to the object. This type of interview elicits richer information than regular interviews because images and objects facilitate recalling processes and memories in more detail (Harper, 2002). For this project, a protocol was developed to contribute to the understanding of participants' development in the project's three foci (STEM, making, entrepreneurship). The protocol started the conversation around how they approached the design and making process, with follow-up prompts about process, design, idea gathering, and prototyping. Artifact elicitation interviews took place utilizing different formats and contexts, depending on the specific circumstances of the program. For example, some artifact elicitations were recorded by the participants themselves responding to a short set of questions provided by the research team. Other interviews were conducted by the program's facilitator as part of the debriefing process at the end of some sessions. Most artifact elicitation interviews were conducted by members of the research team as part of the data collection efforts at the beginning and at the end of each eight-week program cycle.

The role of the research team regarding its presence at the makerspace changed over the duration of the project. The first author (who was also the project's PI) was an ongoing presence at the makerspace during its first year. During the second year of the project, he moved away, so his presence was more intermittent, focusing on key moments to collect data for the project, such as the beginning or the end of a session. The second and third authors were present at key moments to collect data, such as to gather the pre/post surveys and to conduct artifact elicitation with participants. All authors participated in the PDR process and conducted data analysis.

4.3. Data Analysis Methods

We used deductive coding (Fereday & Muir-Cochrane, 2006) to analyze artifact elicitation interview transcripts. We pre-selected a set of deductive codes based on our theoretical framework, including our five criteria for assessing agency, to identify sections of transcripts that exemplified each of the criteria. After deductive coding, we conducted thematic analysis (Fereday & Muir-Cochrane, 2006) to group codes into three broad themes: exploration, problem solving, and entrepreneurship.

4.4. Context and Participants

TERC worked with the Forge Greensboro, a makerspace in the Southeastern U.S., to develop and implement AAMASE, which integrated STEM and entrepreneurship into an

eight-week program for middle and high school young women, serving over 50 youth over two years. The research insights shared below are based on data from four groups that participated in the program for eight weeks each. In each of the first five sessions of an AAMASE program, youth were introduced to a different making discipline such as resin, woodworking, pottery, laser cutting, metalworking, 3D printing, sewing, and electronics. These disciplines were chosen in community with the participants. As a kind of capstone, for the final three sessions, youth were presented with a selection of 12 design challenges to solve a problem for a facilitator-created youth persona. Youth had full agency in selecting which challenge they wanted to take on, as well as choice in how they wanted to address the design challenge with access to multiple making disciplines, materials and making mentors around the Forge. Entrepreneurship was integrated throughout by implementing a series of strategies that included the following: participants developed their brand concept; they learned about business concepts (e.g., costs, labor, and marketing); and youth showcased their project and their business ideas in a final project presentation that included discussion of their brand, business concepts, and the problem their product contributed to address.

Each group had about 10 middle and high school age young women who were mostly African American, but also included white, Hawaiian Native, and Latina young women. Three participant cohorts were recruited through out-of-school learning organizations that had existing youth-serving programs, and one cohort was recruited from a local private school.

In this paper, we focus on three young women, Ciera, Addison, and Nora (all names are pseudonyms). Ciera and Nora were in their last year of high school, and Addison was in her first year of high school. Both Ciera and Addison participated in two rounds of the eight-week program cycles, and Nora participated in a single round. All three young women were African American young women and participated in artifact elicitation through self-recording and during data collection conducted by program researchers. The three young women came to the program through AAMASE's partnerships with local youth development groups, with Ciera and Addison coming through one partner and Nora coming through a different one. These three young women were selected for this chapter due to a few reasons. They were willing to talk with researchers and were quite articulate in their answers to our questions, which is not always the case with youth participants. We also had more videos from Ciera (7) and Addison (5) than other participants because they participated in two rounds, so we had more opportunities to conduct artifact elicitation interviews with them. We had three videos featuring Nora. The three cases presented here reflect the broader patterns observed among project participants, though with richer examples than other participants.

4.5. Limitations

Given that the analysis focuses on three individual case studies, this chapter's purpose is to provide an in-depth, contextualized, and holistic understanding of three individuals' experiences and use of agency in their participation in a program in a makerspace. Given the use of qualitative methods, these insights do not seek generalizability; rather, we used contextualized insights to answer how and why a program focused on making supports these three young women's agency, which is something that quantitative methods would not be able to answer.

5. FINDINGS. SUPPORTING AGENCY THROUGH MAKING

The application of the five criteria to assess agency through the interview transcripts with AAMASE youth serves to show examples of how each criterion may appear in the data and to provide proof of concept of this new model. In addition, this model can be used to guide practitioners in the implementation of programs that support agency development among non-dominant youth in makerspaces.

Given our working definition of agency, in addition to organizing the project to be an agency-supportive environment more generally, the specific learning activities and youth-centered pedagogy in AAMASE aimed to support the five-criteria framework of agency that we have defined above: self-efficacy, personalization, connection, planfulness, and iteration. A single making activity might incorporate support for all five of the criteria or just a subset, but no activity failed to support multiple. We found that exploring making disciplines through single-day activities supported personalization, connection, and self-efficacy, while engaging in problem solving through longer final projects provided opportunities for participants to engage in planfulness and iteration. We also found that exploring making disciplines in the context of entrepreneurship development supported personalization, planfulness, and connection. We explore three cases, Ciera, Addison, and Nora, that provide examples of how the five elements of agency were supported through AAMASE.

5.1. Supporting Agency Through Exploration

One of the single-day activities where youth explored a making discipline engaged participants in a resin art project. This meant that, unless they chose to use resin for their final project, youth typically did not get to fully iterate using this discipline. Youth worked with a mentor to experience the fundamentals of resin art as well as some of its chemistry. Youth were provided with coaster molds and various materials that could be used inside of the resin (e.g., flowers, leaves, glitter). Youth were also welcome to further personalize their projects using their own materials.

Ciera participated in two AAMASE sessions, so she got to experience most disciplines twice, which allowed her to gain meaningful experience and iterate on her ideas. She was particularly excited about the array of possibilities that working with resin afforded. She appreciated the creativity afforded by this medium in the making of objects that were both visually attractive and useful.

5.1.1. Personalization

Ciera provided an example of personalization through her engagement with her resin project, which she attempted to make more relevant to her life by making autonomous choices about its style. Ciera decided to personalize her project by incorporating a photocard of two K-pop stars, a unique decoration that she had brought, into her resin coaster pour (see Figure 1). In her artifact elicitation interview with a researcher, Ciera expressed excitement about her coaster because of its novelty. She explained that using the photocard brought a part of herself into the project:

> *It kind of gave it a little bit more meaning because, even though it's a piece of cardboard, you know, with two random people who probably will never know me, it brings me joy, ... making this whole piece that I know that no one else in the world*

could basically remake because of how different epoxy is, it kind of makes it all a little bit more, ... gives a little bit more worth to me.

Ciera personalized the resin project, making it more relevant for herself by adding her favorite artists' photo directly into her resin pour. The open nature of the project made this possible. While the product (coaster) was the same for all students, it was open as to how they decorated and made the final product their own.

Figure 1.
Photograph of Ciera's resin coaster in which she incorporated a photo card.

5.1.2. Connection

Ciera's resin coaster project provided an example of the agency criterion of connection by bringing it together with her notion of herself and her sense of being a creative person. Ciera considered this project to be an opportunity to use her creativity and making something bespoke. She explained,

It's awesome ... I like this project a lot because it has a lot of creativity and uniqueness with it. You know, you could all be given the exact same materials and everyone could create something completely different. I like [it] because you can express your individuality, and you can basically bring yourself into your piece. And then your piece is an extension of you.

Ciera's project further demonstrated the agency element of connection as it connected her to peers through their shared interest in K-pop. In her artifact elicitation, Ciera intimated, "I kinda had [my friend] in mind when I made it." This kind of youth-driven connection to others through making was common in the AAMASE program.

5.1.3. Self-Efficacy

Ciera also demonstrated the agency criterion of self-efficacy by showing her awareness that the effort she put into her projects influenced her success. She showed that she had a sense of competence and that she was aware of the impact of her actions on herself and others. She was proud of what she created and was able to use the materials to make something personal. She shared that AAMASE provided her with a space to explore her creativity and even to get to know herself better, a key developmental milestone for teenagers. She stated,

> *While I'm here at the Forge, I want to dive into my own creativity. I haven't been able to connect as well to my creative side, and I feel like, if I can, then I can get to know myself better. Plus, the more you create, the more creative you are, then, the more pieces of yourself that you get to make. And that can make others happy; it can make you happy.*

In addition, she considered using her creativity to contribute to others' happiness, building her interest in helping others. To support youth in experiencing their "creative side", projects must support youths' agency and support them in engaging in ways that connect to themselves. Ciera talked about making by using pieces of herself, clearly understanding the importance of personalization in the making process.

In her second time participating in AAMASE, Ciera's choice of making discipline to address the capstone design challenge provided strong evidence of her self-efficacy, her belief that she could work towards a successful build. Ciera chose to crochet a shopping tote even though crochet was not one of the disciplines supported through the program. Ciera learned to crochet on her own (through YouTube), and she did, indeed, crochet a shopping tote.

5.2. Supporting Agency through Problem Solving

Addison participated in AAMASE twice, which meant that she did two final projects where she had two opportunities to iterate her use of a making discipline and plan a final project to solve a problem. Her two final projects were clay flowerpots and a laser-engraved chopping board. Her flowerpot project was in response to a design profile where the persona, a plant enthusiast, was looking for a fun and unique way to hold her numerous houseplants. The second project responded to a design profile where the persona is learning to cook and needs a confidence boost in the kitchen.

During one of the artifact elicitation interviews, Addison mentioned that pottery was her favorite making discipline of all those she tried in AAMASE. She saw it as a hobby that she would like to pursue in the future, so she was excited whenever she had an opportunity to work with clay in the program and enthusiastically jumped at the opportunity to have her final project use pottery.

5.2.1. Iteration

Addison provided an example of the agency criterion of iteration by talking about the qualities of different types of clay and how she had learned about each and used this knowledge wo improve upon her designs. Addison's eagerness to work with clay provided her with opportunities to try different pottery techniques, such as hand building and using the pottery wheel, and to use different types of clay, such as stoneware clay and terracotta. When hand building the flowerpots for her first final project, Addison used two different types of clay, which allowed her to iterate and improve upon the techniques that she had learned in previous projects (see Figure 2). She explained,

> *I made this [small rectangular planter] in [AAMASE] today. I'm not done with it. I have to add little pegs to it. But it's going to eventually be a tiny plant pot for succulents and stuff. And then I made this [larger house-shaped planter]. ... It's going to be a house for bigger plants that are going to go inside. And I think the biggest problem that I had was this one [small rectangular planter], because this is a different type of clay. This is terracotta and it's like, I don't know. .... This one [larger house-shaped planter clay] is easier to deal with, to mold stuff together and put it together. This one [small rectangular planter clay] is thinner, I guess. So, I definitely learned to be patient in the process of making them and then something that would help other people maybe in the future.*

Not only did Addison learn to be patient but also considered using her pottery skills as something that can help others in the future by being able to make useful things for them or to teach them these skills.

Figure 2.
Photograph of AAMASE participant, Addison, presenting her small rectangular planter.

5.2.2. Planfulness

Addison provided an example of the agency criterion of planfulness by showing that she had implemented a plan in the making of a project. When working on her second final project (a cutting board with two engraved hearts), Addison kept in mind what she had learned in a previous project where the group used the laser engraver to plan for the cutting board. The first project Addison created using the laser engraver as part of AAMASE involved making a journal with wooden covers where participants laser engraved images that represented them. She and the group found that the laser burned the wood beyond the line of the image they wanted to engrave, creating a burnt shadow around the lines (see Figure 3). So, the group devised a solution: to cover the areas that were going to be engraved with tape so that the tape would dissipate heat from the base material adjacent to the engraved line and they would not have the unwanted shadow. Addison explained,

Researcher: How did you do the hearts?
Addison: Oh, we had used the laser engraver out there, and we had looked up a picture online, and then we had put it in the computer and then on the little website thing that the thing is connected to. And then we had to put tape over it so it wouldn't burn the wood that much. I don't know how to explain it, but when we had made the journals, we didn't put tape over it. So, it gave it that burning look on the outside, instead of just a clear line. ... The tape, it kind of blocked that, so it was just straight lines instead. ... And it just went straight through the tape and then we just peeled it off.

Her previous experience with the laser engraver allowed Addison to be planful in how to implement the necessary steps to produce the final project that she had in mind.

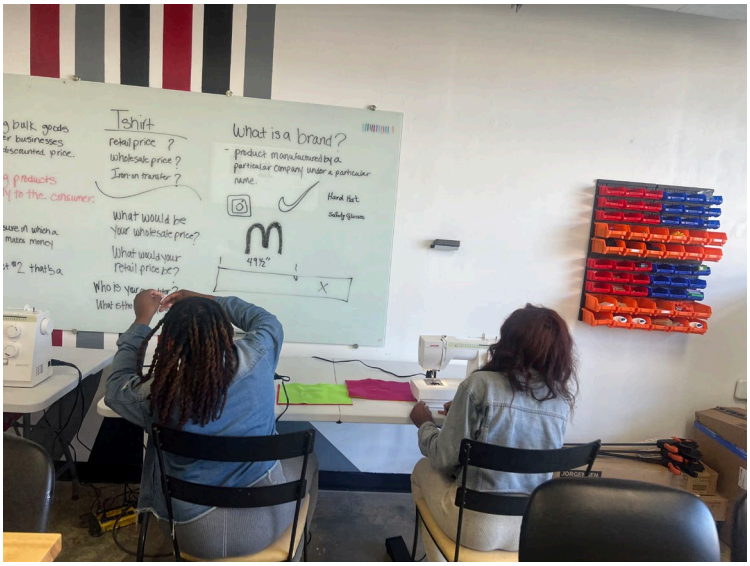
Figure 3.
Photograph of AAMASE participant, Addison, holding the laser engraved wooden journal cover that she created in her initial work with the laser engraver.

5.3. Supporting Agency through Entrepreneurship

The focus on entrepreneurship in AAMASE increased through the program's iterations. Initially, the program had one day when the main focus was entrepreneurship, and then, in their final presentation at the end of the session, participants addressed their plan to market the product they designed for their final project. In later iterations, entrepreneurship was woven into every week's content and even in the space's decorations and enrichment signage (see figure 4).

Nora participated in AAMASE in one of its later iterations, when entrepreneurship was embedded throughout the program. Like other AAMASE participants, Nora was excited about the idea of creating her own products and brand, and was eager to share her ideas with the researchers.

Figure 4.
Photograph of two AAMASE participants learning to use sewing machines. On the wall in front of them, there is a board with entrepreneurship concepts, including considerations when developing a product such as a t-shirt, a definition a brand is, and channels that can be used to market a product.



5.3.1. Personalization

Nora provided an example of the agency criterion of personalization by developing a brand that articulated her choices and opinions without the need for outside approval, expressing her freedom and personal voice. Nora took the opportunity to personalize what she did in the program; she designed her own brand, positioning it so that it represented her and her ideas, and defining her products and how she wanted to sell them:

> *My brand, it says it's "Mars World" because it's about me. … I would mainly make T-shirts or weird socks … The ceramics … I like weird stuff like little, tiny creatures, but they would be cute. My brain is like the mixture between cute and edgy.*

She wanted her products and brand to reflect her feeling of being different from other youth her age, with an emphasis on creating idiosyncratic products that reflected her personality. Nora also thought that the program was empowering:

> *[I was excited about the program because of] the pottery and the fashion aspect of it. And then how [it] is majority based on females empowering each other.*

Not only did the program allow her to explore her interests in making disciplines that she got to learn and practice, but it also provided a space for young women to support each other in very practical ways.

5.3.2. Planfulness

Nora provided an example of the agency criterion of planfulness by showing that she pursued the development of one of her projects based on a well-thought-out plan. For her final project, Nora decided to create jewelry for her school's prom to planfully solve a problem that she had identified. She had noticed that costume jewelry is not very durable and often turns green, which can irritate the skin. To prevent this from happening, she used resin, a durable and hypoallergenic material. She made a bracelet, earrings, and a necklace charm for herself and her friends in the program:

> *The main concern about what to fix, I guess, would be like, you know how jewelry turns your neck or your finger or something green. ... I want to make it out of resin, so it doesn't do that.*

In addition to having a defined idea for her brand and her products, Nora also had a marketing plan. She planned to sell her products through Instagram and Etsy and have her friends use her products in school as a way to advertise them by exposing other school peers to them.

Figure 5.
Photograph of two of Nora's projects: resin jewelry to avoid the potential of discoloring the wearer's skin, and her decorated journal. The journal cover shows the cute and edgy aesthetics that Nora wanted for her brand.

5.3.3. Connection

Nora provided an example of the agency criterion of connection by showing her sense of belonging to a community at the same time that she showed critical consciousness about social inequities and stereotypes imposed onto her community. Through the development of her brand, Nora explored the connection between her identity as a young Black woman and

her community of origin, looking for ways to reframe and reinterpret the stereotypes that are imposed on the Black community. She stated,

> *Just, you know, being where I grew up, reckless is considered being ghetto. But I view reckless as, like, you expressing yourself without giving regards to what anybody else thinks about you. ... And that's how I view myself. So, I would say I'm really not a reckless person. But, you know, ... I don't really care what anybody has to say. So why should you?*

Here, Nora challenged existing stereotypes about being ghetto and reckless, presenting them in a positive light where being reckless is a way of being unapologetically oneself. With the reinterpretation of this stereotype, Nora presents herself and her community through a creative and self-reliant lens, which she hopes will be inspiring to those in her community to live beyond the stereotypes.

6. FUTURE RESEARCH DIRECTIONS

Given that the five-criteria framework to assess agency is a newly developed theoretical framework that has been applied only to the current study, it should be further implemented and researched in other makerspaces to test its fit and better understand its potential for application in other educational settings (e.g., library or school-based makerspaces, after-school programs focused on making) and with different populations (e.g., youth from different racial/ethnic backgrounds, different ages).

For community-based makerspaces to serve their whole community, programs should attend to the interests, abilities, and circumstances of those populations that they currently are not serving in an effort to bring everyone in. We recommend the implementation and study of participatory design strategies and youth-centered pedagogical practices to successfully broaden the makerspace's community of makers. The co-design process has three main steps: (1) *ask participating youth* what they want to accomplish, attending particularly to how projects can help support the development of their agency; (2) *listen* to what they have to say; and (3) *support* them towards their goals authentically so that facilitators can attend to the different elements of agency and ensure that youth of all backgrounds have opportunities to strengthen their agency at every step. Throughout the process, participatory design research methods should be implemented to better understand how agency development is implemented and achieved through the project, particularly with non-dominant youth.

Additional research should gather the existing validated instruments used to measure agency to identify the items that best align with the five-criteria framework for assessing agency among non-dominant youth in a makerspace. Once these items are identified, the instrument should be implemented and validated with participants in makerspaces. This process would support the development of a comprehensive instrument specifically conceived for measuring agency among non-dominant youth in makerspaces.

7. CONCLUSIONS

Given the lack of consensus on agency in the literature, we developed a five-criteria framework to assess agency in the context of working with non-dominant youth in makerspaces. The five criteria include self-efficacy, personalization, connection, planfulness, and iteration. This framework is not meant to be exhaustive or applicable in all educational

settings since it was developed in the context of a makerspace and with the purpose of understanding how a PDR making program with non-dominant youth supports their agency. It may be useful, however, as a steppingstone for those interested in systematizing their understanding of how their programs support youths' agency development.

We found that, to better support young women's agency in makerspaces, programs should be organized to center the participants' learning interests and focusing the learning activities on their experiences instead of on a set curriculum with specified goal products. We found that this new framework to assess agency was a useful tool to understand how AAMASE supported non-dominant youths' agency in a makerspace through some of the most common activities in makerspaces, such as exploring new making disciplines, engaging in problem solving, and getting immersed in entrepreneurship:

Supporting agency through exploration. The structure of AAMASE making activities, and particularly the one-day activities where participants explored a making discipline, supported participants' agency most frequently through encouraging *self-efficacy*, *personalization*, and *connection*. Exploring new making disciplines provided opportunities to try new materials, learn how they responded to different treatments, and test different ideas and ways to address issues.

Supporting agency through problem solving. Final projects where youth considered how to solve a problem using one of the making disciplines that participants had previously explored supported their *planfulness* and *iteration*. This was possible because they had the opportunity to consider different solutions to the problem and how the different disciplines may or may not accomplish that. They were also able to test how their solutions worked and improve upon previous iterations.

Supporting agency through entrepreneurship. The implementation of entrepreneurship as one of the axes of the program provided opportunities for *personalization, planfulness,* and *connection* by presenting the youth with the opportunities to design not only products, but a brand that encompassed a personality, the solution of a problem, and a target customer.

The AAMASE participants reported and displayed high engagement and enjoyment. Additionally, Ciera, Addison, and Nora showed interest in using their newly acquired making skills to help others by making objects that they could use, by teaching them these same skills, or by redefining stereotypes imposed on communities. Experiences like Ciera's, Addison's, Nora's, and those of their peers are key to supporting their agency and engaging young women in STEM-rich learning experiences, which ultimately leads to broadening STEM opportunities for all. Given that learning, including the development of agency, through making is often implicit, having the tools to identify it and make it explicit will support the value of learning through making in out-of-school environments for all youth.

REFERENCES

Bandura, A., Barbaranelli, C., Caprara, G. V., & Pastorelli, C. (2001). Self-efficacy beliefs as shapers of children's aspirations and career trajectories. *Child Development*, *72*(1), 187-206. https://doi.org/10.1111/1467-8624.00273

Bentley-Edwards, K. L. (2016). Hope, agency, or disconnect: Scale construction for measures of Black racial cohesion and dissonance. *Journal of Black Psychology, 42*(1), 73-99. https://doi.org/10.1177/0095798414557670

Calabrese Barton, A., Tan, E., Greenberg, D. (2017). The makerspace movement: Sites of possibilities for equitable opportunities to engage underrepresented youth in STEM. *Teachers College Record, 119*(7), 1-44. https://doi.org/10.1177/016146811711900608

Calabrese Barton, A., & Tan, E. (2018). A longitudinal study of equity-oriented STEM-rich making among youth from historically marginalized communities. *American Educational Research Journal, 55*(4), 761-800. https://doi.org/10.3102/0002831218758668

Castek, J., Schira Hagerman, M., & Woodard, R. (2019). *Principles for equity-centered design of STEAM learning-through-making*. Tucson: University of Arizona. Retrieved from https://circlcenter.org/wp-content/uploads/2019/10/Castek-STEAM-Learning-Making-Whitepaper.pdf

Cavazzoni, F., Fiorini, A. & Veronese, G. (Eds.). (2022). How do we assess how agentic we are? A literature review of existing instruments to evaluate and measure individuals' agency. *Social Indicators Research, 159*, 1125-1153. https://doi.org/10.1007/s11205-021-02791-8

Champion, D. N., Tucker-Raymond, E., Millner, A., Gravel, B., Wright, C. G., Likely, R., Allen-Handy, A. & Dandridge, T. M. (2020). (Designing for) learning computational STEM and arts integration in culturally sustaining learning ecologies. *Information and Learning Sciences, 121*(9-10), 785-804. https://doi.org/10.1108/ILS-01-2020-0018

Coenraad, M., Palmer, J., Franklin, D., & Weintrop, D. (2019, June). Enacting identities: Participatory design as a context for youth to reflect, project, and apply their emerging identities. *Proceedings of the 18th ACM International Conference on Interaction Design and Children,* (pp. 185-196). https://doi.org/10.1145/3311927.3323148

Creswell, J. W. (2021). *A concise introduction to mixed methods research*. SAGE publications.

Douglas, E., Jordan, S., Lande, M., & Bumbaco, A. (2015, June). Artifact elicitation as a method of qualitative inquiry in engineering education. *122nd ASEE Annual Conference & Exposition,* Seattle, WA. https://doi.org/10.18260/p.23574

Fayolle, A., & Gailly, B. (2015). The impact of entrepreneurship education on entrepreneurial attitudes and intention: Hysteresis and persistence. *Journal of Small Business Management, 53*(1), 75-93. https://doi.org/10.1111/jsbm.12065

Fereday, J., & Muir-Cochrane, E. (2006). Demonstrating rigor using thematic analysis: A hybrid approach of inductive and deductive coding and theme development. *International Journal of Qualitative Methods, 5*(1), 80-92. https://doi.org/10.1177/160940690600500107

Gravel, B., Tucker-Raymond, E., Kohberger, K., & Browne, K. (2018). Navigating worlds of information: Literacy practices of experienced makers. *International Journal of Technology and Design Education*, *28*(4), 921-938. https://doi.org/10.1007/s10798-017-9422-3

Greene, J. C. (2007). *Mixed methods in social inquiry*. John Wiley & Sons.

Harper, D. (2002). Talking about pictures: A case for photo elicitation. *Visual Studies*, *17*(1), 13-26. https://doi.org/10.1080/14725860220137345

Hitlin, S., & Elder Jr, G. H. (2006). Agency: An empirical model of an abstract concept. *Advances in Life Course Research, 11*, 33-67. https://doi.org/10.1016/S1040-2608(06)11002-3

Kajamaa, A., & Kumpulainen, K. (2019). Agency in the making: Analyzing students' transformative agency in a school-based makerspace. *Mind, Culture, and Activity*, 26(3), 266-281.

Kennedy, T. J., & Odell, M. R. L. (2014). Engaging students in STEM education. *Science Education International*, *25*(3), 246-258. Retrieved from https://files.eric.ed.gov/fulltext/EJ1044508.pdf

Knudsen, J., Jaumot-Pascual, N., & Levin-Guracar, E. (2025, January). Maker and math identity in an afterschool making program with a focus on Latinx youth. *CRAFT Newsletter*.

Lautamo, T., Paltamaa, J., Moilanen, J., & Malinen, K. (2020). Psychometric properties of the Assessment Tool for Perceived Agency (ATPA-22)–utility for the rehabilitation of young adults not in education, employment or training (NEETs). *Scandinavian Journal of Occupational Therapy*, *28*(2), 97-109. https://doi.org/10.1080/11038128.2020.1782983

Levin-Güracar, E., Jaumot-Pascual, N., Rafanan, K., Lara-Meloy, T., Eways, J. & Mitchell, I. (2024, September). *Object elicitation interviews: Engaging youth in conversations about their STEM learning through making*. Presented at the annual Association of Science and Technology Centers Conference, Chicago, IL, United States.

Marsh, J., Arnseth, H. C., & Kumpulainen, K. (2018). Maker literacies and maker citizenship in the MakEY (Makerspaces in the Early Years) project. *Multimodal Technologies and Interaction*, *2*(3), 50.

Martin, B. C., McNally, J. J., & Kay, M. J. (2013). Examining the formation of human capital in entrepreneurship: A meta-analysis of entrepreneurship education outcomes. *Journal of Business Venturing, 28*(2), 211-224. https://doi.org/10.1016/j.jbusvent.2012.03.002

Martin, L. (2015). The Promise of the Maker Movement for Education. *Journal of Pre-College Engineering Education Research* (J-PEER), *5*(1), 4. https://doi.org/10.7771/2157-9288.1099

Nabi, G., Liñán, F., Fayolle, A., Krueger, N., & Walmsley, A. (2017). The impact of entrepreneurship education in higher education: A systematic review and research agenda. *Academy of Management Learning & Education, 16*(2), 277-299. https://doi.org/10.5465/amle.2015.0026

NGSS Lead States. (2013). *Next Generation Science Standards: For states, by states*. Washington, DC: The National Academy Press. https://doi.org/10.17226/18290

Schouweiler, D., & Heredia, S. C. (2021). Balancing individual and collective agency in informal STEM learning experiences. *Connected Science Learning, 3*(1), 12318678.

Stevens, J. W. (2002). *Smart and sassy: The strengths of inner-city Black girls*. Oxford University Press.

Tan, E., Calabrese Barton, A., Kang, H., & O'Neill, T. (2013). Desiring a career in STEM-related fields: How middle school girls articulate and negotiate identities-in-practice in science. J*ournal of Research in Science Teaching*, *50*(10), 1143-1179. https://doi.org/10.1002/tea.21123

Wardrip, P., Evancho, J., & McNamara, A. (2018). Identifying what matters. *Phi Delta Kappan*, *99*(6), 60-63. https://doi.org/10.1177/0031721718762425

Weiss, J., Anisimova, T., Shirokova, G., & Durst, S. (2023). The entrepreneurial gender gap: The role of in-group support and national embeddedness values in young women's entrepreneurship. *International Small Business Journal, 41*(8), 843-872.

Weiss, C. (1995). Nothing as practical as good theory: Exploring theory-based evaluation for comprehensive community initiatives for children and families. In J. Connell, A. Kubisch, L. Schorr, & C. Weiss (Eds.), *New Approaches to Evaluating Community Initiatives*. Washington, DC: Aspen Institute.

Vossoughi, S., Escudé, M., Kong, F., & Hooper, P. (2013, October). *Tinkering, learning & equity in the after-school setting*. Paper presented at the annual FabLearn Conference, Stanford, CA.

Zimmerman, L. A., Li, M., Moreau, C., Wilopo, S., & Blum, R. (2019). Measuring agency as a dimension of empowerment among young adolescents globally; findings from the Global Early Adolescent Study. *SSM-Population Health*, *8*, 100454. https://doi.org/10.1016/j.ssmph.2019.100454

ACKNOWLEDGMENTS

The authors extend our gratitude to Ciera, Addison, Nora, and all the participants of the AAMASE program for their enthusiasm for the program and their eagerness to participate in our research. The authors also thank The Forge for being such willing partners in this endeavor. The authors also want to thank Kenya Freeman for her work in organizing data and starting to develop individual case studies. This material is based upon work supported by the National Science Foundation ITEST Program (award #2148543). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

AUTHORS' INFORMATION

Full name: Ken Rafanan
Institutional affiliation: TERC
Institutional address: 2067 Massachusetts Avenue, Cambridge MA 02140
Short biographical sketch: Ken Rafanan is a Senior STEM Education Researcher at TERC who partners with community members to develop learning activity systems integrating professional development, curriculum, assessment, and technology designed to develop learners' agency and enhance learning of STEM disciplines. Ken's recent work has focused on the use of making to support learning for students in and out of school. In addition to leading the AAMASE project, he was a co-PI on an NSF-AISL funded research project to develop and research an after-school program designed to engage rural, Latinx youth in design thinking and math through making. Ken is an avid maker with a focus on ceramics.

Full name: Nuria Jaumot-Pascual, Ph.D.
Institutional affiliation: TERC
Institutional address: 2067 Massachusetts Avenue, Cambridge MA 02140
Short biographical sketch: Nuria Jaumot-Pascual, Ph.D. is a Research Scientist at TERC. She leads studies on the experiences of minoritized people in STEM education through participatory design research, creative methods, and meta-synthesis. She is Co-PI in two NSF-funded projects and a Spencer Foundation project. She has a Ph.D. in Qualitative Research Methodologies from the University of Georgia. As a maker, she enjoys collaging and making modified books using recycled and reused materials. She is currently experimenting with mono printing.

Full name: Elise Levin-Güracar
Institutional affiliation: TERC
Institutional address: 2067 Massachusetts Avenue, Cambridge MA 02140
Short biographical sketch: Elise Levin-Güracar is a math educator and a researcher at TERC. She participates on both design and research teams. She studied education, public policy, and sociology at the University of California at Berkeley, and is currently pursuing a Master's in Mathematics Education Research at Berkeley. Her research interests include: middle school mathematics, mathematical argumentation, teacher professional development, curriculum design, and embodied learning. She continues to teach math to first- through eleventh-graders. As a maker, she enjoys gardening, playing with acrylic paint, and learning new crafts (most recently ceramics and water marbling).

Full name: Teresa Lara-Meloy
Institutional affiliation: TERC
Institutional address: 2067 Massachusetts Avenue, Cambridge MA 02140
Short biographical sketch: Teresa Lara-Meloy is a Senior Math Education Designer at TERC. She has grown as researcher and designer over 25 years and is currently principal investigator for projects attending to supporting youth and professionals as they learn and teach middle school mathematics. Her interests include math argumentation, the role of making and dynamic representational technologies in learning, the benefits of multilingualism, and improv-enabled models of professional development.