

“LIFE IS YOUR BLOCK OF CLAY.” APPLYING A TYPOLOGY FOR LEARNING IN MAKERSPACES

Nuria Jaumot-Pascual¹, Teresa Lara-Meloy¹, Ken Rafanan¹, & Elise Levin-Güracar²

¹*TERC, Inc. (USA)*

²*University of California, Berkeley (USA)*

Abstract

This paper contributes to identifying the often-implicit learning that minoritized youth do in community-based making in makerspaces and afterschool programs. We apply Tomko and colleagues' (2023) typology for learning in makerspaces to artifact elicitation transcripts from two projects that integrated math/STEM and making with minoritized youth to test its applicability to a younger population and a different setting. The implementation of this typology identifies both how and what individuals learn through making activities and the gaps we find in the framework when applying it to learning in informal spaces. Given that learning through making is often implicit, having the tools to identify it and make it explicit supports the value of learning through making in out-of-school environments for minoritized youth.

Keywords: *Makerspaces, typology for learning, modes of learning, products of learning, artifact elicitation.*

1. Introduction

Tomko et al.'s (2023) Typology for Learning Framework (TLF) is a classification of university students' learning in engineering program makerspaces. Our team applied this framework to the data we collected in two projects via artifact elicitation interviews with participating youth. These two projects integrated community-based math/STEM and making in the United States: AAMASE, with middle and high school Black young women in a makerspace and AMPED4Making, with middle school Latine youth in an afterschool program. In these projects, researchers and community partners co-designed curriculum that integrated math/STEM and making through activities that were culturally relevant and that reflected the youth's interests. Youth designed projects that addressed community problems of their choosing. The projects' research, which informed the iterative development of the curriculum, used artifact elicitation interviews as a key data gathering strategy.

2. Theoretical framework and literature review

Tomko and colleagues' (2023) TLF includes two main categories with their corresponding subcategories: (1) modes of learning (learning by doing, and learning through others/communicating and managing), and (2) products of learning (content knowledge and skills, cultural knowledge and skills, ingenuity, and self-awareness). We applied TLF to the projects' artifact elicitation interview data to test its applicability to middle and high school youth. We consider that this typology can help educators identify the learning that occurs through making as well as support the identification of activities that support those types of learnings.

Artifact elicitation is a data collection method that uses objects made by program youth to center the conversation (Douglas et al., 2015). Participant-generated objects embody the knowledge, skills, and attitudes held by the youth that made them and elicit the motivations and feelings they had when they made them. The youth were excited to share what they made and how they made it. Typical questions included: How did you design this object? What challenges did you face? If you made it again, what would you do differently? This method allowed us to gather data on the youth's making and learning process using a format that worked with the programs' regular flow.

3. Research design and methods

The purpose of this study is to test the applicability of TLF to middle and high school youth and to see how it supports the identification of different types of learning in informal learning spaces that

involve making. In Tomko et al.'s (2023) study, participants were university students in an engineering design class who participated in three 90-minute individual interviews that were spaced out over 3 weeks. In contrast, our participants were middle and high school youth in two out-of-school making programs. We conducted opt-in artifact elicitation interviews once a semester. Many were group interviews of up to 4 youth that lasted 5-10 minutes each (Levin-Gürcar et al., 2024).

The study's high school-aged youth attended an eight-week long program comprised of 3-hour sessions weekly in a local makerspace, where they learned from a program facilitator, expert makers, and entrepreneurs (Rafanan et al., 2025). The study's middle school-aged youth attended a ten-week long afterschool program comprised of hour-long weekly sessions at their schools, facilitated by a youth educator (Jaumot-Pascual et al., 2025).

We analyzed six artifact elicitation interviews from three participants: Rose and Pedro, both seventh graders, and Serena, a high school junior. All three participated in at least two artifact elicitation interviews. Initially, they were not used to being interviewed given their ages and the informal setting. However, since they participated in repeated program cycles and were interviewed multiple times, they became familiar with the interviews. The setting and associated lack of formal assessment also contributed to their comfort and reduced their urge to provide socially desirable responses. We used TLF to deductively code the transcripts using its categories and subcategories as our codebook.

4. Findings and discussion: Typologies of learning observed

Although the participants and the setting in Tomko et al.'s (2023) study and ours are different, we found that TLF was generally applicable to both our study participants and settings, supporting the identification of different types of learning. We use the TLF structure to provide examples for many TLF categories and subcategories.

1. Learning by Doing is the discussion of "learning through experiences as a direct result of one's own actions," and includes five subcategories: (1.1) *Failing*, (1.2) *Struggling*, (1.3) *Practicing*, (1.4) *Iterating*, and (1.5) *Exploring* (Tomko et al., 2023, p. 6). We found evidence of participants* talking about making mistakes and iterating. Serena's discussion of her challenges in throwing a cup on the pottery wheel is an example of (1.1) *Failing* and (1.2) *Struggling*. She was able to articulate how she failed and how she tried to solve the issue:

This one right here [picks up a short light blue ceramic cup]. I had a difficult time with throwing this. ... So, like, you'll see a little hole in it. In the inside, you can see, like, how it has a little hole in it. That's when I was throwing it, and I went down too deep. And we tried to bring it up. It really didn't go up as well. So, it's a little deep hole and then you have a hole on the side.

The following quote by Rose, where she talked about playfully practicing her sewing and using the tools of the craft, is an example of the (1.3) *Practicing* and (1.5) *Exploring* subcategories: "I used to sew when I was younger. I have, like a, like a grid thing to let me practice with it. So, I was just like, sewing on that, just messing with it."

Some *Learning by Doing* subcategories were not as prevalent in our data due to the program's structure, which provided projects to explore different making disciplines but did not include opportunities to iterate failed projects. However, youth were aware of how they would iterate a project if they got a chance, as we see later with Serena's clay project in category (3) *Content and Skills*.

2. Learning through Others/Communicating & Managing is the "discussion of seeing what other people are doing or interacting with other people as a way to beget more understanding of something" (Tomko et al., 2023, p. 6) and includes five subcategories: (2.1) *Observing and Listening*, (2.2) *Collaborating*, (2.3) *Receiving or Soliciting Help or Training*, (2.4) *Giving Help or Instruction*, and (2.5) *Leading, Managing, and Administering*.

Serena's discussion of how her sister helped her while she was making a ceramic heart is an example of subcategory (2.3) *Receiving or Soliciting Help or Training*. She shared, "My [clay] heart didn't work out at first. It's so— My sister told me to just do, like, one side and then do the other side. So, I did that." Though Serena's sister's instructions were simple, they helped her accomplish her goal of making a clay heart.

During our observations of the programs' learning sessions, we often noted participants learning with others and providing instruction to each other. However, these interactions did not tend to appear in the interviews, since youth were used to the program's group-based pedagogical interactions and youth considered collaboration and communication as part of the program's culture, not necessarily part of their learning.

* All participant names are pseudonyms.

3. Content Knowledge and Skills is the “discussion on the knowledge, skills, and technical jargon acquired in various subject areas” (Tomko et al., 2023, p. 6). The subcategories are (3.1) *Design*, (3.2) *Manufacturing and Tools*, (3.3) *Computational Tools*, (3.4) *Materials*, and (3.5) *Components*. This is the category of the TLF for which we have the most examples because it aligns well with the design and maker emphasis in our projects.

In almost every interview, we found evidence of youth talking about the design process, including prototyping, creating, and the reasons for creating and making a design. The following excerpts are examples of the types of conversations that took place in the program around subcategory (3.1) *Design*. Rose, Pedro, and Serena discussed how they ideated their designs for projects that represented their families. Rose explained the steps to build her stuffie by showing how the different parts were integrated to build the whole.

Rose: Okay, this is a stuffie of a muffin.
 Interviewer: Of a muffin?
 Rose: It's a muffin, yeah. Uh.
 Interviewer: Huh. And how did you make it? [To youth who speaks Spanish: ¿Cómo lo hizo?]
 Rose: So, we cut from fabric, right? And then we sew part of it and then stuff it and then sew it back.
 Interviewer: M-hmm. And [how] did you put things on the outside? First? Or later? Like the eyes?
 Rose: Oh, yeah. I put the eyes and the teeth after that, after I was finished [with] the base.
 Interviewer: And why did you make them?
 Rose: A muffin? Because me and my family like to bake. So, one of the things we bake a lot of [is] mostly cupcakes and cake.

Pedro made a stuffie in the shape of a cross, explaining both how it represented his family and the process he used to make it. He stated, “Because my family's religious. And I made it by drawing it on a piece of paper and I cut out the paper, and I made it on a fabric and I traced and I cut the fabric out with the paper and yeah, I just sewed it.”

Serena discussed how she used specific colors in her resin designs as a connection to family members. She stated,

I did this one [picks up a green ceramic cup] for my mom. I wanted to make her something to have to maybe put her jewelry in, you know, whatever she needs to put in it. I put— chose green because, you know, green is really a kind of like a neutral color. So, I just I freestyled on this one with the green. ... My aunt's favorite color is purple. My aunt passed in 2019. So, I made something that [is] a remembrance of her. So, I just put purple flowers in a purple pigment. So, you know, just get that remembrance.

Youth also discussed the materials, tools, and devices they used to create their designs, which we identified as belonging to subcategory (3.2) *Manufacturing and Tools*. Some of these excerpts were as short as naming the machines they used. For example, Serena said, “I know we used a sand[ing] machine.” Sometimes they elaborated on the topic, such as when Pedro shared his sometimes-frustrating experience using a 3D printer, “Yo diría que por suerte. Porque algunos están muy grandes y otros están muy chiquitos. Porque la impresora a veces no puede funcionar tan bien, y tiene problemas al imprimir ciertas piezas. [I would say it was luck. Because some are big and others are small. Because the printer sometimes didn't work as well and it had problems printing certain pieces.]”

Youth in our middle school program worked with CAD software (Tinkercad) and a 3D printer. This drove discussions on the topic of subcategory (3.3) *Computational Tools*, including how they moved between real world measurements and measurements in their 3D designs on the computer.

Rose: We 3D-printed these.
 Interviewer: Ah. You did?
 Rose: Yeah.
 Interviewer: Oh, tell me about that. Me está contando que los imprimieron con la impresora. [She is telling me that they printed them with the printer.]
 Pedro: Ah, sí.
 Rose: It's on this website called TinkerCad. And we did like, measure it and--
 Interviewer: What did you measure?
 Rose: With the millimeters. [Rose takes out the ruler from her cubby.]
 Interviewer: And what were you measuring? ¿Qué midieron?
 Rose: The corners on the box [pointing to the corners]. So, we can put them together ... And then the— we 3D-printed them because we just printed over there ... And then the next time we came over here, we, like, we [stapled] them together to, like, our cubbies.
 Pedro: Yeah, we did. Yeah, we got to design them, and we had to make like a specific like size and [opens his hands to indicate a dimension]. Um. We learned how to do, like, three-dimensional shapes to the dimension.

When it came to describing materials, part of subcategory (3.4), youth had opportunities to discuss novel materials, such as when they worked with clay, resin, and metal. Serena discussed carving a flower into a clay piece:

Interviewer: You mentioned the flower. Is that something maybe that you would like to have worked on more or differently?

Serena: Yeah.

Interviewer: What would you have done differently?

Serena: Not add so much water.

In addition to talking about materials, Serena also talked about how she would do things differently if she got to repeat the project, which is part of TLF's subcategory (1.4) *Iterating*, which we saw earlier.

4. Cultural Knowledge and Skills are the “discussion on navigating a community [in this case, the makerspace community] along with the physical space and what the person comes to understand about that community” (Tomko et al., 2023, p. 6). The subcategories are (4.1) *Access, Conventions, and Protocols*, (4.2) *Roles and Structure of Participation*, (4.3) *Rules of the Community*, and (4.4) *Gender Associations*.

We found that participants often talked about how the program made them feel welcomed and talked about the program's explicit rule of being accepting of everyone and of celebrating experimentation. These comments touched upon elements of all the subcategories withing the (4) *Cultural Knowledge and Skills*, such as access, the structure of participation, and the community's rules. For example, Serena commented,

It felt great, actually, for me to get out [of] my bubble. I really don't get out of my bubble like that. I normally stay close, have my walls up. So, it's like for me to, you know, get outside my bubble, it was very different. I felt welcomed. I felt, you know, I felt everybody's energy, which was a positive energy. They kept [a] smile on their face, you know, they welcomed me, and they said nice things. So, it was very nice to get to experience that.

Given how exclusionary of youth, women, and people of color spaces dedicated to making can be, participants' comments about feeling welcome in the program were a measure of success for the adults involved.

5. Ingenuity is the “discussion on an informal seeking out solutions or being aware of strategies to use in performing a task” (Tomko et al., 2023, p. 6). Ingenuity subcategories include: (5.1) *Improvisation*, (5.2) *Opportunism*, and (5.3) *Resourcefulness*. We did not find examples of this category in the transcripts of the three participants included here, but other participants did talk about improvising new solutions when something else failed, taking advantage of opportunities to be creative, and being resourceful by using materials in unintended ways.

6. Self-Awareness is the “discussion on the motivating factors toward one's attitude along with one's personal attributes/characteristics” (Tomko et al., 2023, p. 6). The subcodes include: (6.1) *Confidence*, (6.2) *Patience*, (6.3) *Resilience*, and (6.4) *Reflection*. Youth in the program reflected on how much they learned, how they felt about their skill levels, and what they gained from their overall participation, which are part of subcategory (6.4) *Reflection*. For example, Rose described that the applied, contextualized math in the program was “different from what we're learning in class,” which was pen-and-paper worksheets, when discussing her stuffie project. She got to apply math to the projects she made in the program, seeing how to use math's to solve problems. Serena also reflected on how she felt about using new machinery, showing self-awareness about her own fears:

Interviewer: OK. Were any of you afraid to use any of the machines?

Serena: I was a little bit. Because it's, like, all the orb machine. I don't know. It's just, I don't use the type of materials or machines on a daily basis. So, it was my first time. So, I got a little scared.

Though she was initially scared of the machines, she was able to overcome her fear. Serena also explained that the program helped her be more self-confident and empowered her to follow her aspirations. She stated,

I feel like the things that we learn here, it's like making us a better person and it's like influenced us to do like, basically, put our minds to what we want to do and like continue going for our dreams. And like, you know, going to that extent where you know you can ask for help when you need it and, like, basically accomplish your dreams. Don't ever be afraid.

5. Limitations

This study's type of data, participants' ages, and the informal learning settings did not match those of Tomko et al.'s (2023) study, which slightly limited the applicability of the TLF. The artifact elicitation interviews in this study were short, which was appropriate for the study's setting and population. However, this also limited the length and depth of discussions with the interviewees, restricting the extent to which

we could observe the modes and products of learning that took place. For example, Pedro and Rose discussed a possible iteration of Pedro's stuffy project and proposed ideas on how to reduce its floppiness. We did not consider their dialogue to fit the TLF's *Learning through Others / Communicating & Managing* category because, while they were engaged in learning through exchange with others, they were not discussing or reflecting upon their learning. Another limitation was the age of this study's participants, with many of our participants being substantially younger than the Tomko et al. (2023) participants. Our participants' younger age meant that they were very aware of age and power differentials with interviewers and were influenced by the presence (or absence) of peers, which affected their willingness to share their ideas and experiences. Conducting group interviews often ameliorated youth's shyness, providing the comfort of a group and opportunities to build on each other's ideas. At the same time, a group setting sometimes triggered giggling sessions or disengaged group attitudes where social pressure superseded the interviewers' efforts to engage the youth in conversation. Including observation data would likely provide examples of some of the subcategories that did not appear in the artifact elicitation interviews.

6. Conclusions

We found the TLF to be applicable to youth of middle and high school age. TLF also helped in identifying some of the learning that happens through making. However, for TLF to better support researchers and educators in making-based informal education programs, we see the need for modifications or extensions. One significant addition that we would make would be to capture learners' motivations for designs and making (e.g., Goldman & Kabayadondo, 2017). The youth in our programs spoke at length about social or relational reasons why they had made things in particular ways. For example, Rose made a stuffie shaped like a muffin, because she and her mother like to bake, and Serena used specific colors in her ceramics work to connect to family members. Because TLF doesn't include a way to identify the aspects of design that involve this communal orientation of making for others, we suggest extending the framework to attend to this critical aspect of making-based learning in informal spaces.

Acknowledgements

The authors extend our gratitude to the participants for their enthusiasm for the programs, and their willingness to participate in our research and share their making and learning experiences. The authors also thank our community partners for their contributions and expertise in co-designing and facilitating the programs. This paper is based upon work supported by the National Science Foundation (NSF) through the (1) ITEST Program (award #2148543) and (2) partially through the AISL Program (award #2215382) until it was prematurely terminated. 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 NSF.

References

- Douglas, E. P., Jordan, S. S., Lande, M., & Bumbaco, A. E. (2015, June), Artifact Elicitation as a Method of Qualitative Inquiry in Engineering Education. *2015 ASEE Annual Conference & Exposition* (pp. 26-235).
- Goldman, S., & Kabayadondo, Z. (2017) *Taking design thinking to school: How the technology of design can transform teachers, learners, and classrooms*. New York: Routledge.
- Jaumot-Pascual, N., Lara-Meloy, T., & Rafanan, K. (2025). Math and making in afterschool. A pedagogic innovation with Latinx middle school youth. In M. Carmo (Ed.), *Education and New Developments 2025*, Volume 2 (pp. 569–573). inScience Press.
- Levin-Gürcar, E., Jaumot-Pascual, N., Rafanan, K., Lara-Meloy, T., Eways, J. & Mitchell, I. (2024, September 28-October 1). *Object elicitation interviews: Engaging youth in conversations about their STEM learning through making* [Conference presentation]. ASTC Annual Conference, Chicago, IL, United States.
- Rafanan, K., Levin-Gürcar, E., Jaumot-Pascual, N., Lara-Meloy, T., Stevens, H., & Knudsen, J. (2025). Young women belong in makerspaces: Developing and detecting young women's agency in making. In M. Carmo (Ed.), *Education and New Developments 2025*, Volume 2 (pp. 411–415). inScience Press.
- Tomko, M., Alemán, M., Nagel, R., Newstetter, W., & Linsey, J. (2023). A typology for learning: Examining how academic makerspaces support learning for students. *Journal of Mechanical Design*, 145(9), 091402.