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RESEARCH REPORT

"We didn't know we were doing science": Engaging with science and mathematics in an afterschool program

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Abstract

An extensive number of empirical research studies support the engagement of young children and youth in out-of-school science, technology, engineering, and/or mathematics learning experiences. In this case study, we add to this knowledge base through examining how rural middle school learners engage with science and math concepts and practices through an afterschool program that emphasized the development of STEM content, skills, and practices using the field of archaeology, as well as Indigenous knowledges, as mediums. Results highlighted how various syncretic approaches within the afterschool program afforded 61 middle school aged learners' opportunities to engage with math and science concepts common to archaeologists and Indigenous peoples. We illustrate this through five "doings." For example, learners engaged in similar science practices to Indigenous peoples through considering how local landscapes and the natural environment informed decisions regarding settlements. This study concludes with recommendations for professional archaeologists and educators to adapt and/or develop a similar afterschool program to support students' participation as ARCH + STEM learners.

Keywords: *Archaeology, Afterschool Program, Middle School, Syncretic Approach*

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A substantial amount of prior research has documented how participating in science, technology, engineering, and/or mathematics (STEM) experiences in informal learning environments[2] has the potential to shape youths' developing identity and self-confidence in STEM (Allen et al., 2019; Young et al., 2019), positively improve youths' perception of STEM careers (Tyler-Wood et al., 2012; Vela et al., 2020), enhance and extend learning of STEM concepts (Duran et al., 2014; Roberts et al., 2018), increase enrollment in advanced STEM courses (Young & Young, 2018), foster problem-solving skills (Allen et al., 2019), and develop and sustain youths' interest in a STEM field (Allen et al., 2019; Soto-Lara et al., 2021). Moreover, such experiences at an early age have been shown to be predictive of post-secondary learners' STEM identity, competence and engagement in science and mathematics (e.g., Dou et al., 2019; Goff et al., 2020; Rodriquez et al., 2019). The majority of research examining youths' participation and growth as STEM learners in informal learning environments is situated within programs and experiences framed within STEM fields such as robotics and game design (Newton et al., 2020), information technology (Duran et al., 2014), and environmental science (Ballard et al., 2017).

In this study, we focused on a novel afterschool program geared towards the development of middle school learners' STEM content, skills, and practices using the field of archaeology and Indigenous knowledges as mediums. To date, there is limited research that provides and examines ARCH+STEM opportunities for youth. Limited prior research highlights the possibility to engage learners in STEM practices and processes through archaeological concepts and Indigenous material culture (e.g., Beatty & Blair, 2015; Ducady et al., 2016; Moe et al., 2016). For example, as part of an archaeology program, students were observed engaging in the practices of observation, using data or evidence to answer a question, developing hypotheses, stating and supporting conclusions, and making inferences based on observations and/or evidence (Ducady et al., 2016; Moe et al., 2016). These are science practices that align with the practices identified by the National Science Teaching Association (2014) as appropriate for students in grades K-12 in the U.S. These science practices are grounded in behaviors and actions that scientists employ as they investigate scientific phenomena. In addition, students have been found to engage in mathematics practices and reasoning while participating in archaeological and Indigenous activities and curriculum (Beatty & Blair, 2015; Ducady et al., 2016). As argued by Beatty and Blair (2015), these opportunities to participate in and connect with Indigenous ways of knowing afforded learners the opportunity to reconceptualize what it means to do math through a humanistic approach, the art of looming beads. For example, students worked with patterns on three levels: (a) the overall pattern, (b) the relationship between columns, and (c) the relationship of the bead within a column.

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[2] The informal learning environment in this study is defined as a voluntary setting with an instructional focus and guidance for learners, does not involve external assessments, embedded in meaningful activity, and includes innovation of new and current knowledge and skills (Rogoff et al., 2016).

In addition, we refer to this program as ARCH+STEM to highlight the integrated nature of STEM, archaeology, and Indigenous knowledges. The history of North American archaeology includes a long record of colonialism expressed as exploitation of archaeological sites for research and teaching, amplified by a disregard for the knowledge of Indigenous peoples (Cowell, 2017; Witt & Hartley, 2020). Today, most archaeologists acknowledge that Indigenous people and their traditional knowledge play critical roles in the process of interpretation and education, fueling a new era of decolonizing the field of archaeology (Atalay, 2012). As part of the afterschool program, educators aimed to provide a place for Indigenous people and traditional knowledge to inform the learning and doing of STEM concepts through integrating Indigenous voices and worldviews (Snively &Williams, 2018). More specifically, educators worked closely with individuals from a Haudenosaunee Nation to make connections to learners' local region, but also because not including their voices and perspectives would continue colonialism through archaeological practices.

Therefore, this study will add to our current knowledge base of STEM-related informal learning environments by answering the following research question: How do middle school aged learners engage with science and mathematics concepts and principles within an afterschool program grounded in archaeology and Indigenous knowledges? In this study, being engaged is characterized as involvement in an activity, in particular being involved in an activity that encourages the application and enactment of science and math concepts and principles. This is not to be confused with engagement, which has been defined as the "intensity and emotional quality of students' involvement" (Pugh et al., 2010, p. 3). Our intent is not to examine learners' level of participation but understand how the afterschool program afforded youth opportunities to "do" math and science through archaeological ideas and concepts. These "doings" are often hidden or implicit within youths' practices as science and math learners (e.g., Lancy, 2012; Simpson et al., 2020), and involve active as opposed to passive participation as learners (Forbes & Skamp, 2019; Zhai et al., 2014). Prior research has highlighted how doing math and science has positive influences on children's perspectives and beliefs of science and math as a field and as a career (e.g., Hacioglu & Gulhan, 2021; Kwon et al., 2021; Vennix et al., 2018). For instance, Forbes and Skamp (2019) noted how Grade 5-6 students' "doing science" shifted their understanding of science as an active human endeavor that includes hands-on collaborative projects. However, students typically have narrow views regarding what constitutes science and mathematics outside of the classroom context as school expectations and ways of operating are in discord with other programs and learning institutions (Archer et al., 2010; Masingila et al., 2011; Narayan et al., 2013; Pattison et al., 2016). For example, Grade 4 students in Singapore drew images that indicated doing science as (a) hands-on investigations, (b) learning from the teacher, (c) completing the workbook, and (d) a social process and not an individual process (Zhai et al., 2014).

As such, this study addresses Penuel's (2016) call for more research on STEM in practice, particularly through supporting learners to find new ways to relate and understand their world, as well as the call by Colaninno (2019) for STEM discipline-based education research in archaeology. Through the results of this study, we make an argument for archaeology and Indigenous perspectives in supporting middle school students' "doing" science and mathematics. We contend that the significance of this study lies in the potential for professional archaeologists and educators in other communities to develop a similar afterschool program to support youths' engagement as STEM learners. This may have long-term implications for who chooses to obtain a degree and career in a STEM field, fields that historically exclude particular social identity groups such as women, persons with disabilities, Indigenous people, as well as individuals who identify as Black or African American or as Hispanic or Latino (NSF, 2023; Ruef et al., 2019). As described by Lancy (2012) and Rahm and Ash (2008), experiences in informal STEM programs, such as the ARCH+STEM program, are part of an accumulation of STEM experiences that will support an individual's development and transformation through experiencing an insider status.

Theoretical Grounding

The afterschool program and research study were guided by humanistic approaches to math and science concepts and processes (e.g., Aikenhead, 2021; Goffney et al., 2018; Simpson & Kastberg, 2022). This is understood in this study "as a human activity, a social phenomenon, part of human culture, historically evolved, and intelligible only in a social context" (Hersh, 1997, as quoted by Skovsmose, 2012, p. 379). As an example, when asked "how far is it to the [Fitzroy] river," 56 Indigenous students responded using a non-standard length of measurement – time it would take to walk to the river (Grootenboer & Sullivan, 2013). Students' responses were social and cultural in nature (Jin, 2021; Owens & Kaleva, 2007), as well as grounded in their experiences and cultural understanding of mathematics (i.e., human sense-making; Aikenhead, 2021). Broadly speaking, integrating this theoretical grounding within the afterschool program plays a role in aiding middle school students in learning "from our more-than-human relatives" through relational understandings of knowing of the local land (Gutiérrez, 2020, p. 380). In this study, humanistic approaches to math and science concepts and processes lied within the intersection of ARCH + STEM as learners are engaged in human activities unique to the field of archaeology, as well as Indigenous perspectives of STEM focused on relationships and being with nature (Garcia-Olp et al., 2020). Such humanistic approaches to engaging learners in STEM are often missing from school contexts (e.g., Duchscherer et al., 2019; Simpson & Kastberg, 2022) and through an informal content lens (Rahm, .2021).

In addition, we drew insight from Vygotsky's (1986) and Saxe et al. (2015) notion of bringing together two forms of cognitive development – scientific concepts and everyday or spontaneous concepts – as there is a possibility for both forms of development to be in interplay with one another (Simpson et al., 2023). Gutiérrez and Jurow (2016) described this as "grow[ing] into each other" (p. 575) as every day and scientific concepts inform and shape one another as opposed to privileging one over another. This is similar to Moje et al. (2004) third space described as the integration of competing and/or alternative spaces, each with their own rules and norms for how to behave and act (e.g., ways of talking). In this study, our interest was not only in engaging students as participants within the intersectionality of everyday knowledges and scientific knowledges in the field of archaeology, but between Western and Indigenous understandings of science and mathematics (Brayboy & Castagno, 2008).

Methods

For this study, we employed a single instrumental case study (Stake, 1995). An instrumental case study afforded researchers the possibility to investigate STEM participation among rural middle school students within an archaeological afterschool program. The afterschool program is "atypical" as little to no published scholarship exists on the extent of supporting the participation of youth as STEM learners through an archaeology afterschool experience. Archaeology has been used in formal learning situations (e.g., Dulnuan & Ledesma, 2020; Popson & Selig, 2019) and other types of informal learning situations and contexts such as simulations, television/media, museums, and field experiences (Rockman, 2003; Thistle, 2012; Watters, 2015).

Program Description

The afterschool program was designed for middle school learners to gain knowledge of and participate in the STEM disciplines as taught through archaeological concepts and Indigenous knowledge of science, particularly Indigenous people's respect for the environment and all its ecological components. In general, modules were initially designed for a summer program and were more fully developed for the afterschool program to bring STEM concepts to the fore. For instance, participants in the summer programs have thrown darts with an atlatl for years, but there was little discussion about the physics behind its use. In the afterschool program, the atlatl was used to discuss levers and force. As another example, one module focused on how archaeologists use the Pythagorean Theorem to construct a 1-meter by 1-meter excavation unit. Students were challenged to employ any strategy to create the perfect square before discussing how the theorem was used to set up an excavation unit. Next, students were provided an opportunity to apply the theorem in their construction of a perfectly square excavation unit.

The program spanned a 10-week period. The focus was on the precontact history of the Northeastern region of the United States because of the ability to make connections to middle school learner's experiences (e.g., fishing and hunting) and local environments (e.g., rivers and archaeological sites). As an example, learners were introduced to how precontact Indigenous people viewed environmental variables to help them form sustainable communities on the landscape. Learners explored the landforms around their school through examining topographic maps and walking around their school grounds. See https://archaeolessons.com/ for a list of topics and plans implemented in the afterschool program.

Context

The data for this study is from three public middle school sites located in rural areas within the same county in New York State. In spring 2021 and fall 2021, the afterschool program took place in Windy School District[3]. The school served approximately 1,528 children living within a 110-square mile radius. The student population across all grade levels was majority White (91%) with 52% identified as economically disadvantaged and a graduation rate of 92% (New York State Education Department [NYSED], 2022). In fall 2021, spring 2022 and fall 2022, the afterschool program was also implemented in Wiley Point School District, which served about 1,329 children living within a 114-square mile radius. The student population was majority White (96%) with 58% identified as economically disadvantaged and a graduation rate of 78% (NYSED, 2022). Lastly, in spring 2022, we worked with Happy Valley School District. This district served about 601 children living within a 91-square mile radius. The student population was majority White (95%) with 6% identified as economically disadvantaged and a graduation rate of 87% (NYSED, 2022). See Table 2 for an overview of the program at each school site.

Table 2.
Site overview

Semester	School	Day(s) of the Week	Length of Time per Day	# of Learners
Spring 2021	Windy	Tuesday, Thursday	1.5 hours	16
Fall 2021	Windy	Tuesday, Thursday	1 hour	15
Fall 2021	Wiley Point	Wednesday	2 hours	26
Spring 2022	Wiley Point	Wednesday	2 hours	8
Spring 2022	Happy Valley	Thursday	2 hours	24
Fall 2022	Wiley Point	Thursday	2 hours	12

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[3] Names of the schools are pseudonyms.

Each school site offered an afterschool snack and late bus transportation for all students, which afforded middle school learners access to the program by eliminating issues of access that are often associated with afterschool programs in geographically rural areas (Collins et al., 2008).

Participants

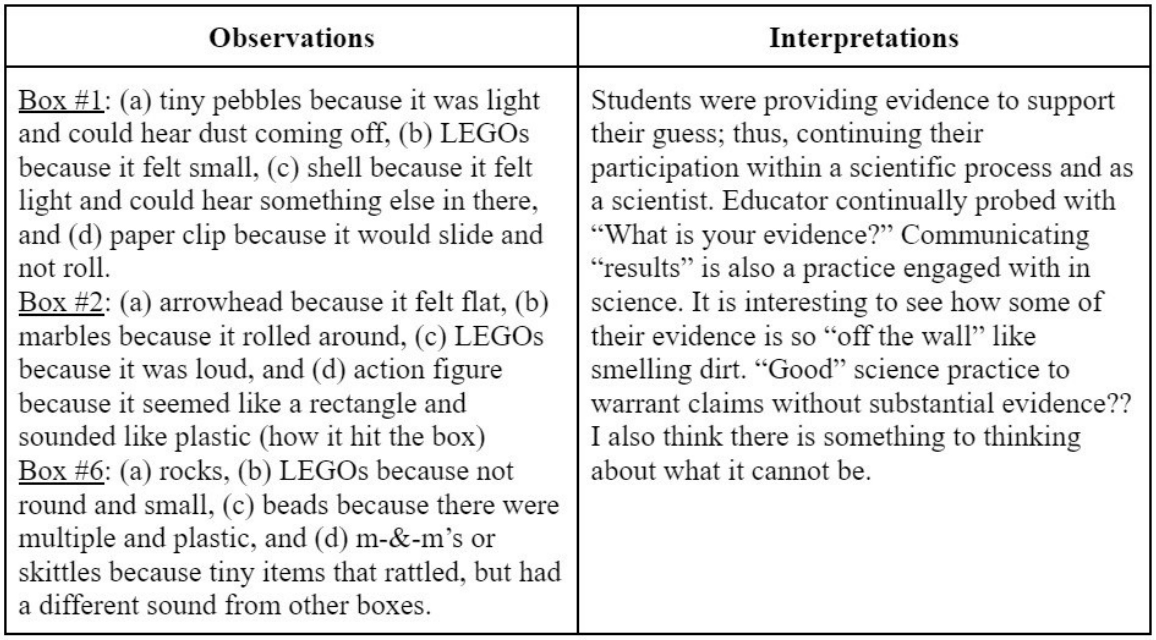
We recruited our participants in collaboration with the three middle schools as information about the program was sent electronically and/or physically to every parent and guardian of learners in Grades 6-8. Over the three semesters, approximately 101 learners across the three sites participated in the afterschool program with 61 providing consent and assent to be a part of the research study. Of the 61 youths participating in the research, 40 (~66%) were in 6th grade, 11 (~18%) in 7th grade, and 10 (~16%) in 8th grade. In addition, three participants (~5%) self-identified as non-binary, one (~2%) as trans male, 28 (~46%) as female, and 24 (~39%) as male. Four participants preferred not to self-identify their gender (~7%) and one noted "still figuring that out." Lastly, the majority of our participants self-identified as White (n = 49, 80%). Six (~10%) participants self-identified as Two or More Races, two (~3%) identified as Asian, and two (~3%) identified as Black. Two preferred not to self-identify their race.

Data Source and Analysis

Field Notes

The main data source for this study was field notes documented by one member of the research team. Field notes were documented approximately once a week during the spring 2021 and fall 2021 programs at Windy Middle School and every Wednesday or Thursday during the programs at Wiley Point Middle School and Happy Valley Middle School. Prior to collecting field notes, we watched a video clip from another research study in which upper elementary aged students worked together to code a robot to traverse a taped path from one side of the room to another. We did not have access to a program or similar data within an archaeological context. The purpose of this was for several reasons. One, to practice documenting verbal and non-verbal acts of communications. Two, to discuss what we observed in terms of students' doing math and science (e.g., practices, skills, and processes). Three, to reflect upon our prior experiences and subjectivities as STEM learners, educators, and/or researchers, and how these informed our observations (e.g., McDonald et al., 2019).

As passive observers, we walked around the periphery of the classroom during whole-group discussions. During small group interactions, we would spend between 5 and 7 minutes at each group before rotating to another group. Within 24 hours of the observations, the written field notes were translated into a two-column document (Stake, 1995). In the left-hand column were the field notes. Field notes documented the verbal and non-verbal ways in which youth engaged in math and science concepts and principles in the program. This included their interactions with one another during small group activities, interactions with educators, and whole-group discussions. These were expanded upon and detail was added to "complete" what we were not able to document in our notes at the time of data collection. The right-hand column included our interpretations as to how learners were engaged in the activity. See Figure 1 for a two-column example from the Hypothesis Testing module. Within this module, groups of learners were given wrapped boxes in which they had to form a hypothesis about what was inside through using their senses to gather evidence (Science Museum Group, n.d.). The example below is from the second half of the activity in which groups of students justified and supported their hypothesis with evidence. Researchers met each week to discuss the observations in terms of how the middle school students engaged in science and math concepts through archaeological concepts and Indigenous ways of viewing science and math.



Observations	**Interpretations**
Box #1: (a) tiny pebbles because it was light and could hear dust coming off, (b) LEGOs because it felt small, (c) shell because it felt light and could hear something else in there, and (d) paper clip because it would slide and not roll. Box #2: (a) arrowhead because it felt flat, (b) marbles because it rolled around, (c) LEGOs because it was loud, and (d) action figure because it seemed like a rectangle and sounded like plastic (how it hit the box) Box #6: (a) rocks, (b) LEGOs because not round and small, (c) beads because there were multiple and plastic, and (d) m-&-m's or skittles because tiny items that rattled, but had a different sound from other boxes.	Students were providing evidence to support their guess; thus, continuing their participation within a scientific process and as a scientist. Educator continually probed with "What is your evidence?" Communicating "results" is also a practice engaged with in science. It is interesting to see how some of their evidence is so "off the wall" like smelling dirt. "Good" science practice to warrant claims without substantial evidence?? I also think there is something to thinking about what it cannot be.

*Figure 1.*Two-column example of field notes

Next, we looked across field notes to consider similarities or patterns in our observations and interpretations. For example, Figure 1 highlights how students were communicating and justifying their hypotheses around what was inside each mystery box through providing evidential claims based on observations. This was communicated through a class discussion. We found other activities that supported this observation. For example, groups of students were observed communicating and defending how they sorted and characterized projectile points to their peers. As such, our focus was not on examining math and science concepts as privileged by state standards but considering how students engaged with science and math concepts and principles through authentic and humanistic approaches (e.g., Moschkovich, 2002; Philip & Azevedo, 2017) common to archaeologists and through Indigenous perspectives.

Focus Group Interviews

Focus group interviews were conducted to promote dialogue regarding participants' lived experiences and interpretations of their participation in the program (Kamberelis & Dimitriadis, 2013). We expected focus groups to promote a kind of "memory synergy" among participants (Kamberelis & Dimitriadis, 2013, p. 40). We further supplemented this with showing them pictures or a list of the various activities in which they engaged throughout the program. Focus group interviews occurred at the conclusion of each 10-week program. We developed the interview questions as a research team. Example questions from the semi-structured protocol included (a) Were there any activities that you can remember using or engaging with math? Tell me more; and (b) Were there any days or activities that you can remember using or engaging with science concepts? Give me an example. The interviews lasted approximately 30 minutes and were conducted in-person by the first author in a classroom at the school. All focus group interviews were audio-recorded and professionally transcribed. Transcripts were reviewed for accuracy and edits were made when necessary.

For this study, the focus group interview data was not analyzed but served as a form of triangulation, a validity procedure to corroborate evidence of the field notes across the different semesters and school sites (Denzin, 1984). Quotes in which students talked about how they engaged with math and science within the various modules were pulled out and compiled by module. We integrated a few quotes within the results to highlight how learners engaged with science and mathematics concepts and principles within the afterschool program. Participant developed pseudonyms are used to refer to learners.

Results

We begin the results with a quote from Timothy (8th grade); "I feel like it kinda changed me 'cause it opened me up to more things. We have a PLTW [Project Lead the Way] program that we use STEM. And I feel like this one kinda opened me a lot more to the archaeology point of STEM." While we cannot claim this to be a similar experience to other participants, this quote highlights how the program was an extension of STEM concepts and practices at his school. In addressing how students engaged with science and mathematics through the various modules within the archaeology afterschool program, we found five "doings" – (a) engaging with math concepts as archaeologists, (b) engaging with science concepts as Indigenous peoples, (c) engaging in math concepts as Indigenous people, (d) engaging in observational skills as archaeologists, and (e) engaging in a scientific process as an archaeologist.

Doing Math Concepts as Archaeologists

Excavation Sites

The standard archaeological excavation unit is a regular square unit, often with each of the four sides measuring exactly one meter. This aids archaeologists in documenting the location of objects recovered within a relatively small area (i.e., $1m^2$ unit). Working in teams of 2-3, learners were first challenged to create a one-meter by one-meter perfect square using four nails and a tape measure (see Figure 2-A).

Figure 2-A

Figure 2-B

Figure 2. Images of learners constructing a $1m^2$ excavation unit

Students were able to place three nails to form two congruent sides of a square, each side measuring 1-meter in length. This is represented in Figure 3. Next, youth used their tape measure to find the distance of 1-meter from Stake 1 (S1) or S3. This is where they would place the fourth stake. When measuring each of the sides again, they determined that not all sides of the square were 1-meter in length. Therefore, placement of the fourth stake involved the mathematics practice of productive struggle as they continued to measure and reposition the stakes in search of a perfect square or excavation unit. As stated by Ezerelda (8th grade), “It was a little bit frustrating because you'd have to like, keep putting it in and, like, keep trying to make it even.”

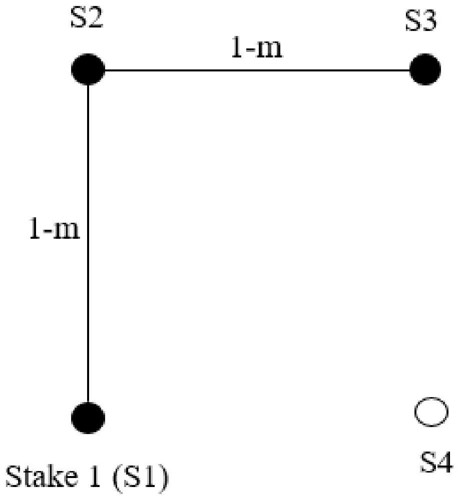


Figure 3. Diagram of creating a perfect square using trial and error

After approximately 15-minutes, students were presented with the Pythagorean Theorem, which states that the square of the length of the hypotenuse of a right triangle is equal to the sum of the squares of the lengths of the other sides or the legs (i.e., $a^2 + b^2 = c^2$). Collectively, the middle school participants found the hypotenuse to be approximately 1.41 meters in length. This theorem is often utilized by archaeologists when laying out excavation units because it produces a more precise square. As illustrated in Figure 2-B, one learner held the end of a tape measure with a length of 1-meter at one stake, while an educator held the end of another tape measure measuring about 1.41 meters at another stake. Another learner joined the two tape measures at a point where the two tape measures crossed. This is where a third stake was placed. This process was repeated to place the fourth stake. Tyra (6th grade) described this as "Yeah, so you had to go this way [formed diagonal across body with right arm]. This way [formed diagonal across body with left arm]. This way [both arms vertical], and this way [both arms horizontal]."

Lastly, this activity engaged students in utilizing a meter as the unit of measurement. This was novel as learners in the U.S are not often introduced to the metric system, but the Imperial system (e.g., feet). As we observed, learners were somewhat confused by this unit of length. For example, asking "what is a meter?" Or "how many centimeters is a meter?" Hence, middle school participants engaged in using a form of measurement more common to the practices of archaeologists than supported in their school experiences. We have evidence from one focus group interview in which a meter was discussed within this activity, and only this activity. As stated by Kit-Kat (7th grade), "They [archaeologists] used certain measurements for like certain things." Greg (7th grade) elaborated upon this as he noted how archaeologists "used one meter by one meter, I think, sized cubes of area of work."

Orienteering

In this module, learners explored how to navigate their surroundings with a compass, which is a tool archaeologists use to make maps of a project or site and to navigate the landscape in order to locate geographic features or sites when doing fieldwork. After exploring how a compass worked (e.g., hold flat in hand and in front of your stomach), learners used spatial reasoning skills as they oriented and positioned their bodies in the direction of north or when moving their bodies 160 degrees using the compass as a guide. Three groups of learners then used this skill to lay out a straight line due 180 degrees south and measured 30 meters in length. They placed a pin flag every 4 meters (see Figure 4-A). This simulated an archaeologist marking locations where they would systematically excavate across a landform to look for cultural material. Throughout this activity, learners were observed using their compass to ensure that their line was straight or 180 degrees south (i.e., spatial reasoning; see Figure 4-B). When asked how he knew he was consistently heading in the appropriate direction, Eastern (6th grade) stated "the red arrow is pointing at him."


Figure 4-A Figure 4-B

Figure 4. Use of the compass to ensure laying a straight line

At the end of this activity, the three lines of pin flags should be parallel to on another. We observed an interaction between an educator and a sixth-grade student, Lion, regarding this. "Do you think it looks parallel? How can we test?" Lion pointed from one flag in one line to another flag in another line, but did not articulate anything verbally. When probed further, Lion stated "they never touch." This alone did not imply that the lines in this activity were parallel lines. The educator followed by asking, "but how do you know?" Lion eventually indicated measuring the distance between two lines from start to end and the distance should be the same. Lion also seemed to have another idea as he added "or make sure each flag is 180 degrees south," which could be an appropriate approach based on the learners' body position.

The last part of this activity engaged students in counting the number of paces to walk 15 meters. They were then asked to calculate the number of steps they would walk if they needed to find 10 meters. As explained, sometimes it is not possible to use a tape measure to measure how far archaeologists are walking. In such cases, knowing their pace helps them measure how far they walked without using a tape measure every time. We observed students engage in different approaches to solving this. Ken (6th grade), for example, began by dividing his pace of 17 by three as he was then going to double this amount to find his pace for 10 meters. While thinking of this appropriately, the division was difficult for Ken. Koko, on the other hand, inappropriately added her pace of 15 steps, ten times to equal 150 steps. In an interview, Iguana (6th grade) chose logician/mathematician as one of their identities as they recalled "doing those weird wide lines and using math to figure how much each of my steps were."

Doing science concepts as an archaeologist: Faunal Analysis

The goal of this activity was for learners to participate in the process of faunal analysis as they identified animal bone types and the animal to which the bone belonged (e.g., cow, pig, deer). In our field notes, we noted how middle school participants were asked questions that encouraged observation (e.g., "What do you notice? Does that look like anything on the table?"), exploration (e.g., "Keep looking. Don't give up."), and comparing and contrasting their bones to those from a collection (e.g., "How is it similar or different to the bone in your hand?"). Learners were observed considering the texture of the bones, putting bones together for fit, and discussing the color of the bones (see Figure 5). These practices of observing, exploring, and comparing are foundational ways of engaging with science as an archaeologist. In the interviews, learners also highlighted the practices of observation and exploration. For example, Zorea (8th grade) stated, "We were looking at the bones and matching certain parts of the parts, even though I got a bit frustrated once or twice. Like, I got a piece that looked like an adult and had like very smooth edges. But then it's not like an adult. So, it's like, is this a teenager? Or is it the size of a baby, but more have adult features? Is this even the right animal at this point?"

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Figure 5. Participating as a faunal analyst

Doing math concepts as Indigenous peoples

Stone Tools/Flintknapping

Flintknapping is also a process that engaged STEM learners in applying various concepts, namely, geology, physics, and mathematics concepts. Flintknapping is the making of stone tools from lithic raw materials such as chert, jasper, and obsidian. Only stones with particular attributes can be used to make tools (e.g., brittle, no internal fracture planes, elastic, etc.). The manner in which the material breaks can then be determined by the knapper and their application of force. In our field notes, we documented students being presented with different types of stones found in the local area and asked to consider the properties to look for in stones that could be used for flintknapping. Responses from students included "rocks that are thinner" and "break in certain ways." Eventually, students were provided with an opportunity to participate in the process of flintknapping. This process required students to hit the edge of the raw material with a hammerstone or an antler billet at an angle less than 90˚ (see Figure 6-A). The energy passes through the material in the shape of a cone, allowing a flake to be removed. As stated by an educator, "It's gotta be less than 90 degrees. The closer to 90 degrees, the larger the chunk." This process was also grounded in physics concepts as the hammerstone transferred energy when hitting the stone. Once students had a flake, they participated in the tool making process, which required youth to use an antler tine to remove smaller flakes (pressure flake) and shape it into a tool like a projectile point (see Figure 6-B). This task requires the same knowledge about the raw material and angles to remove flakes of a certain size and from particular areas of the larger piece. Students often used their flakes to cut different materials such as leather and tree branches. In one observation, North and Octonaut (6th grade) struggled to cut through leather, stating, "This tool isn't super sharp."

Figure 6-A Figure 6-B

Figure 6. Students participating in flintknapping and tool making

In our observation, some students may or may not have been aware of how to apply these concepts when producing flakes. We heard educators providing guidance such as "how about we turn it because remember we are looking for that angle" and "…look at how you are holding it. We want to hold it at a tilt so we can chip away a piece of flake and not explode the material." On the other hand, when asked why he tried to hit a rock at a certain angle, North stated, "I decide the angle based off of where the energy should be placed to cut through the rock." Another student, Jimeboop (6th grade) added, "If you hold the antler up further it provides less force when you hit the rock and if you hold it closer to the base, it creates more force."

Doing science concepts as Indigenous peoples:

Atlatl

An atlatl, or spear thrower, is a stick or short pole in which the end of a dart is inserted into a wood or bone hook (see Figure 7). The use of an atlatl allows for the dart to be thrown farther and with more force than if thrown only by hand. Learners were first introduced to the physics behind throwing a dart with an atlatl. We documented phrases such as "potentially increase the amount of force/distance," "...by pulling back, it builds up force," "your arm serves as a lever and fulcrum with a pivot point," and "each one builds up additional force." As such, the atlatl serves as an extension of an individual's arm and acts as a lever when thrown. For instance, the extension of the forearm (i.e., forward throwing motion) uses the elbow as the pivot point or the fulcrum. The flick of the wrist at the end of the throwing motion also serves as a lever system. The triceps produce the force to throw a dart with an atlatl with very little motion. As depicted in Figure 7, youth engaged in throwing darts using an atlatl; therefore, applying the physics concepts as STEM learners in the program, as well as mirroring the actions of Indigenous people.

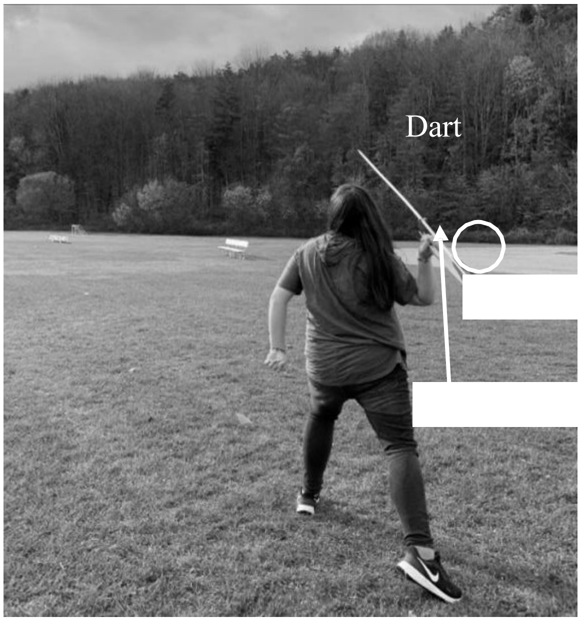


Figure 7. Image of using an atlatl

Further, as noted in observations, students also chose to throw their darts differently to determine the best method – turning torso to throw, standing still and only moving arm/wrist, and running prior to throwing – as well as where to hold the atlatl – closer to the front or closer to the back. Therefore, some students informally engaged in a science process of experimenting with different variables, observing and collecting data, and interpreting their results. Following the action of throwing with the atlatl, we also noted students being able to discuss how different variables impacted how far they threw a dart. For example, one student noted how the different characteristics of the three atlatls used seemed to have impacted how they threw the dart. Arm position and the release point were other variables discussed. This highlighted learners' engagement with science as they considered how different factors may influence the results of how far a dart is thrown.

In the interviews, middle school participants often related science to this activity. On a rudimentary level, Ezerelda (8th grade) noted science was involved in "how you throw the atlatl." Students were able to describe factors that may or may not have affected how far the dart was thrown. The following example from two 6th graders, Tyra and Eve, highlights how the strength of an individual and an individual's throwing style were two factors considered. Tyra noted, "You don't have to be really strong to be able to do it. You just need force." Eve added, "Yeah, and certain ways you throw it can affect how far it goes or how high. And if you let it go down here, it's going to hit the ground." In addition, students used language grounded in the physics concepts introduced by educators (e.g., levers, force). As one example from a focus group, Casey (8th grade) stated, "…like the levers, and then the force. And I know force is like a Newton thing."

Greg built upon this, “You use your arm as a lever and the atlatl as a lever to make the spear go farther.” However, this was also an activity in which students expressed the “hidden” nature of science within their actions This was expressed well in the following comment by Kitkat: “I think the atlatls because when we were doing them, we didn't really think about science, we were just like having fun, just throwing them. We weren't really thinking about the science behind it. After a few tries, I realized that I put force on it, and that's when I realized that was like science.”

Landscapes

In this module, learners considered how Indigenous people determined what landscapes (i.e.., floodplains, terraces, and uplands) were best for habitation sites, and which areas were best for specific land use activities, such as fishing, plant collecting, and hunting. Learners explored these ideas through landscapes around their school. For example, learners at Windy Middle School were given a scenario that positioned them to think as people who lived hundreds or thousands of years ago. “Consider if that hill was covered with snow. As a south facing hill, what happens when the sun comes out? The snow will melt, which means the animals will come out and eat nibbly things. Was this a good place for people to live?” A few students responded with yes. Elliot (8th grade) added that this would only be ideal temporarily as living near a river might be ideal in summer months. As another example, learners at Happy Valley explored areas near a river that flowed by their school (i.e., floodplain). As asked by an educator, “would this be a good place to have your village?” Students responded with no because there was a high chance of flooding. “Where would be a good place for the village?” Learners discussed across the river where there was a higher elevation. “What might you do right here [on the floodplain]?” One student shouted out fishing, but not gardening. They further inquired about being able to make pottery due to the amounts of clay. As these examples highlight, learners were gaining an understanding of how the various landscapes and the natural environment informed decisions regarding settlements of Indigenous peoples.

Doing a Scientific Process: Research Projects

Near the end of the program, learners had the opportunity to engage with science and mathematics, as well as professional archaeologists, as they worked in groups to define and implement their own research study. This study was based on an archaeological topic of interest to them, specifically a topic grounded in their prior participation in the program. To illustrate, we present the research project of three learners – Leonardo, Timothy, and Poly. Through the program, they learned how Indigenous people used raw materials like bone, wood, and stone/flake for different functions. The purpose of their study was to determine which raw materials scraped, cut, and drilled the best (see Figure 8-A). They hypothesized that the flake would cut, scrape, and drill the best. The experiment included scraping, cutting, and drilling a carrot five times using the three different tools (see Figure 8-B). As a specific example from their poster, "we took the three tools and used a cutting motion on a carrot five times. Then we measured how deep the cuts went into the carrot." They concluded that their hypothesis was incorrect as the results highlighted a flake was best for scraping, wood for cutting, and bone for drilling.

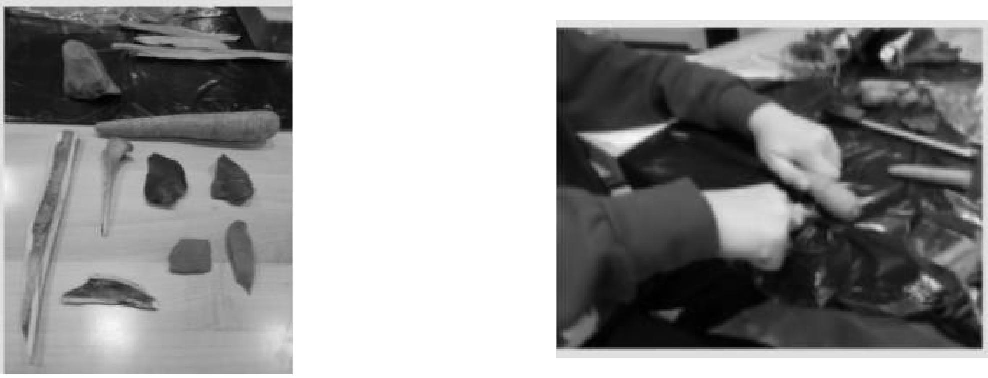
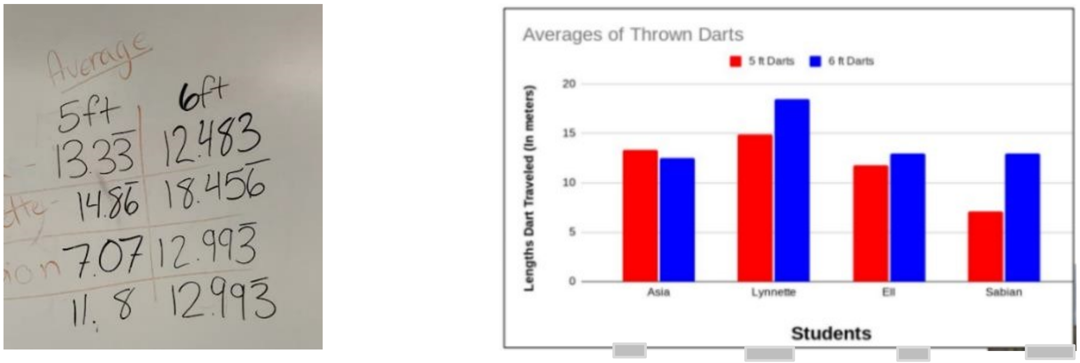


Figure 8-A Figure 8-B

Figure 8. Image of raw materials and cutting motion

Next, learners created a poster based on their research. As described by one of the educators of the afterschool program, "All scientists have to present their research, but it is not helpful if we are only speaking with one another in the research field. Research should also be presented to the public. One way to do this is posters." Field notes confirmed learners' "doing" research similar to the professional practice of STEM professionals as their posters included an abstract, an objective, materials, methods, results, conclusions, and references, if applicable. Learners engaged as a collaborative team of scientists in creating their posters. One new skill a majority of the learners gained was how to create graphs in Google Sheets. As an example, one group calculated the average throws per person based on their hypothesis that a short dart would be thrown further than a long dart when thrown with an atlatl (see Figure 9).



Average

	5ft	6ft
-	$13.3\overline{3}$	12.483
tte-	$14.8\overline{6}$	$18.45\overline{6}$
ion	7.07	$12.99\overline{3}$
	11.8	$12.99\overline{3}$

Figure 9. Results presented as averages in a table and a bar graph created in Google Sheets

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Lastly, learners presented and communicated their research through an archaeological perspective to the public (e.g., teachers, parents, administrators) by participating in a poster session at their school. The posters served as a visual modality and were written to be understandable to a range of individuals. In our observations, we often described how the research projects provided students with hands-on explorations (i.e., learning through doing), as well as engaging them in "hidden" science and mathematics practices with a focus on archaeology and/or Indigenous ways of being and living. For instance, a group of three students created and tested the strength of cordage, which is fiber strands twisted together to make rope or string. Through testing how much weight their cordage would hold, students were engaged in foundational principles of materials science and engineering.

Discussion

In this paper, we illustrated how an archaeological afterschool program supported middle school learners in the "doing" of science and mathematics practices and concepts; thus, addressing Penuel's (2016) call for more research on ways to support learners in finding new ways to understand their world through STEM. As such, similar to the research of Saxe et al. (2015) and Gutiérrez and Jurow (2016), we made a case for the syncretic approach of ARCH + STEM through highlighting how archaeology and Indigenous knowledges may play a role in middle school learners' engagement with science and mathematics. It was through the afterschool program that participants had opportunities to enact humanistic approaches of STEM processes and practices of archaeologists and Indigenous peoples, as well as enhance and/or connect learners' participation in mathematics and science practices, process, and concepts within a learning environment that is often positioned and defined as an alternative to a more formal learning environment such as a school setting (i.e., two ends of a spectrum; Folkestad, 2006; Lange & Costley, 2015). This was observed through five doings, namely by engaging with math and science concepts as archaeologists, math and science concepts as Indigenous peoples, and a scientific process as an archaeologist. Based on prior literature, it is likely that these experiences supported middle school learners' ability to make connections and reconceptualize what it means to do science and mathematics (Beatty & Blair, 2015), as well as shift their perspective of mathematics and science as a human endeavor that involves collaboration and exploration (Forbes & Skamp, 2019; Kwon et al., 2021).

Educators in this program often questioned if and when to name particular participations as science or mathematics within the afterschool program as the goal was not to engage learners in approaches more common to formal settings. However, we acknowledge how participation in science or mathematics activities through archaeology may foreground learners' developing practices and knowledge as mathematicians and scientists without their ability to identify and/or explicitly articulate this (e.g., seeds of algebraic thinking; Levin & Walkoe, 2022). Additionally, we acknowledge that the results of this study hold promise in terms of a diverse and inclusive STEM workforce as prior research in informal learning environments has shown the potential to positively develop and maintain youths' interest, identity, and knowledge in STEM (e.g., Vela et al., 2020; Young et al., 2019); factors that have been shown to influence one's decisions to pursue a degree and career in a STEM field (e.g., Godwin et al., 2016; Maltese et al., 2014).

We contend that the significance of this study lies in the potential for professional archaeologists and educators in other communities to develop a similar afterschool program as a way to support learners' engagement with math and science concepts and practices. Based on our experiences, we provide a few recommendations when adapting and/or developing a similar program for middle school learners. First, create and implement archaeological concepts and Indigenous ways of knowing that allow for exploration and application of STEM concepts, skills, and practices that are connected to, yet "hidden" from, formal schooling standards. Second, engage learners in authentic activities that allow them to participate in the practice of archaeology, ones that allow them to struggle or even fail. Third, allow students to follow multiple pathways to achieve the various goals grounded in science and mathematics concepts and practices.

Further, we acknowledge two limitations of this case study. First, observations of the various STEM practices within the program were colored by each individual's perspective, understanding, and experiences as STEM learners and educators. While some may view this as a limitation, we view this as a strength as we were not seeking agreement, but wanted to gain a more holistic picture of how middle school students participated as STEM learners through the afterschool program (Denzin, 1984). Second, lacking the ability to generalize findings from this study may be viewed as a limitation. For example, some may argue that the results from the localized nature of the Indigenous perspectives and ways of doing STEM as not widely applicable to other regions. Yet as argued by Flyvberg (2006), "generalizations are overvalued as a source of scientific development" (p. 12). Lincoln and Guba (1985) proposed a similar argument as Flyvberg and considered transferability, or the extent to which results are transferable to similar contexts, as an alternative approach. Therefore, future research within similar contexts has the potential to generate concrete universals regarding ways to support middle school learners' engagement with science and math through archaeological concepts and Indigenous ways of knowing (Erickson, 1986).

Conclusion

We conclude with the following quote from *A Science Framework for K-12 Science Education* (National Research Council, 2011).

> Our expectation is that students will themselves engage in the practices and not merely learn about them secondhand. Students cannot comprehend scientific practices, not fully appreciate the nature of scientific knowledge itself, without directly experiencing those practices for themselves (p. 30).

In this study, we illustrated how learners engaged in and experienced math and science practices and concepts common to archaeologists and Indigenous peoples. This study holds promise for how to engage and enhance learners' science and mathematics concepts, practices, and processes through concepts and material culture that are often not a part of K-12 school curriculum.

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