Final Project

Broadening Indigenous Youth Participation in Computing Education

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Introduction

Currently, K-12 education systems around the world are emphasizing the importance of youth from all cultures becoming "not just consumers, but producers of [technology]" (Litts, Searle, Brayboy & Kafai, 2020, p.843). Despite the movement towards more equitable and inclusive computing[1] education, Sandoval (2019) describes computing as "one of the most segregated fields" (p.129) towards Indigenous[2] peoples. This segregation is evident; Indigenous engagement in computer science (CS) and admittance into technology-related fields are alarmingly low (Kafai, Searle, Martinez, Brayboy, 2014; Biin & Weston, 2015). For example, in the 2019 Taulbee Survey, American Indian/ Alaska Native graduates were only 0.2% of the recipients of CS graduate degrees (Zweben & Bizot, 2019). While such statistics reflect the negative status of Indigenous students in the field, in this paper, I[3] sought to conduct a literature review for supporting educational success among Indigenous students in computing rather than focusing on the deficit discourse that faults Indigenous populations (Tuck, 2009). This work also investigates the computational platforms in use as they are integral elements for engaging Indigenous youth.

Bridging the two worlds

The tension between computing and Indigenous knowledge systems is not new (Bowers, Vasquez & Roaf, 2000). Computer science(s) is based on the "cultureless" ultimate truth systems of extraction and is largely virtual, linear, and static (Ben-Ari, 1998; Eglash et al., 2020a). In contrast, Indigenous knowledge is holistic and expressed through land-based education, which engages the geographical, relational, and experiential domains of place (Barnhardt & Kawagley, 2005). Paralleling this complexity, the technology platforms generalized for all people are not "culturally neutral" instruments; their intended features, capabilities, and uses are shaped by the

cultural landscape from which they are manifested (Bowers et al., 2000). Métis media artist Jon Corbett (2008) reflected on the limitations of programming environments while coding his First Nations' hand-beaded portrait. His implementation of the beading practice using the conventional "nested-loop" repetition structure was uncomplicated (Corbett, 2008) (see the left side of figure [1]). However, he encountered complexity while reformatting his code to match the Indigenous methodological practice of beading (from left to right then right to left in a continuous line) because programming instructions don't support it (Corbett, 2008; Corbett, 2018) (see the right side of figure [1]).

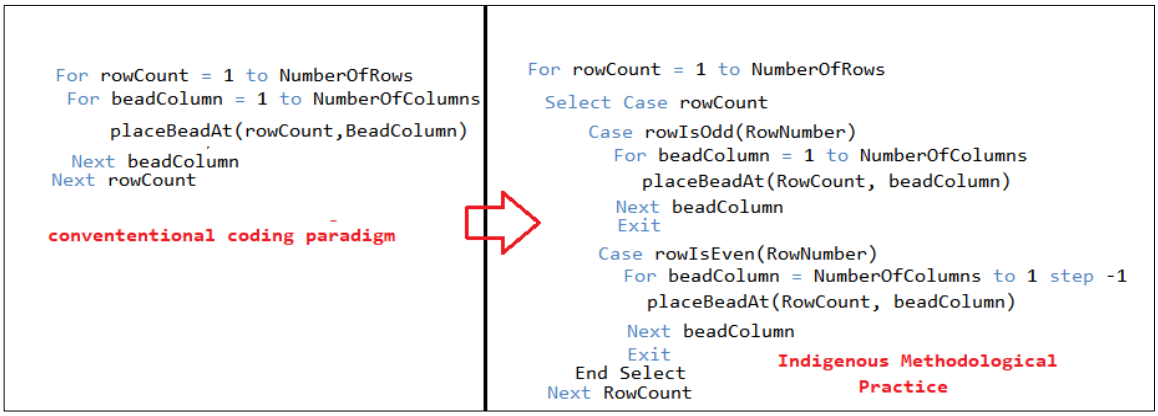

Figure [1]: Indigenous beading: Conventional programming paradigm versus the Indigenous methodology (Corbett, 2008, p.23-24)

Despite the disparity between views and the viable allegations raised against technology platforms, several researchers see the potential of bridging and connecting (e.g., Abdilla & Fitch, 2016; Lewis, 2014; Sandoval, 2019). Following Barnhardt and Kawagley's "two-way street" (2005, p. 3) approach and Mi'kmaw's Elder Albert Marshall "two-eyed seeing" concept (The Green Interview, 2018), they believe that computer practitioners can leverage the strengths of both perspectives to develop new pathways in education and production. For instance, Abdilla suggests that using the "Indigenous pattern thinking" may enable seeing all the angles in balance

and avoid the technological singularity predicted by Stephen Hawking in the Artificial Intelligence field (Abdilla & Fitch, 2016).

Indigenous knowledge in computer education literature

Throughout the past two decades, there is an increased awareness of the racial/ethnic gap in computing and the challenges to the achievement posed by cultural mismatch (Pohawpatchoko, 2018). However, most research and culturally responsive reforms have focused mainly on African-American and Hispanic youth (mainly published in the United States context), and it appears that Indigenous students have been neglected even in the minority educational reforms and practice (Pohawpatchoko, 2018). Figure [2] illustrates the limited research contributing to improving computing design and education for Indigenous youth.

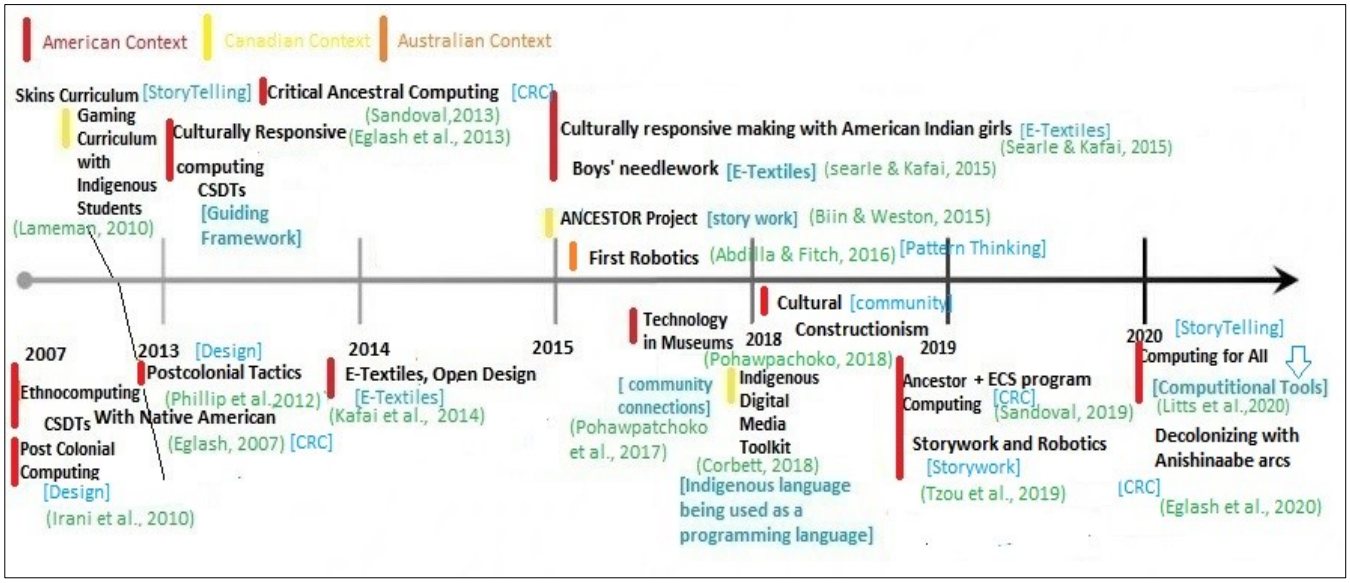

Figure [2]: Literature addressing broadening participation in three different contexts.

Another critical note, most research was conducted in out-of-school settings (e.g., Skins workshops). While informal learning environments are beneficial, the current state of Indigenous underrepresentation will not improve without more attention to culturally responsive approaches in the school settings. The few formal studies show examples of profound involvement with

culture-computing links and cases where more development is required (e.g., Sandoval, 2019). Below is a brief overview of published research addressing ways to empower Indigenous youth in computing. I organized the articles into six identifiable themes or strategies; however, some articles may fit across multiple themes.

[1] Ethnocomputing with Indigenous knowledge

Ethnocomputing is a framework that suggests that computing principles should be related to the local cultural systems at multiple levels, including algorithms, design models, interfaces, and educational practices (Tedre, Sutinen, Kahkonen & Kommers, 2006). This framework has led the way to culturally responsive computing (CRC), a field focusing on raising the achievement and interest of "underrepresented ethnic groups" in computing education (Eglash, Gilbert & Foster, 2013). One key goal of CRC is critiquing the structural conditions (e.g., colonialism) that caused students' underrepresentation and refuting the colonial myth of "primitivism" as well as the racist stereotypes of IQ and "math genes" (Eglash et al., 2013). Another goal of CRC is connecting computing content with heritage and vernacular cultural practices and/or social-justice issues that are familiar to students (Eglash et al., 2013; Sandoval, 2019). And thus, computing can be "part of the repertoire of healthy identity self-construction" (Eglash et al., 2013, p.36). One of the best examples of CRC is the Culturally Situated Design Tools (CSDTs) created in collaboration with and for "Native American" communities (see figure [3]), where, for instance, Shoshone beadwork is mapped into a Cartesian coordinate and learners design on Virtual Bead Loom (Eglash, 2007).

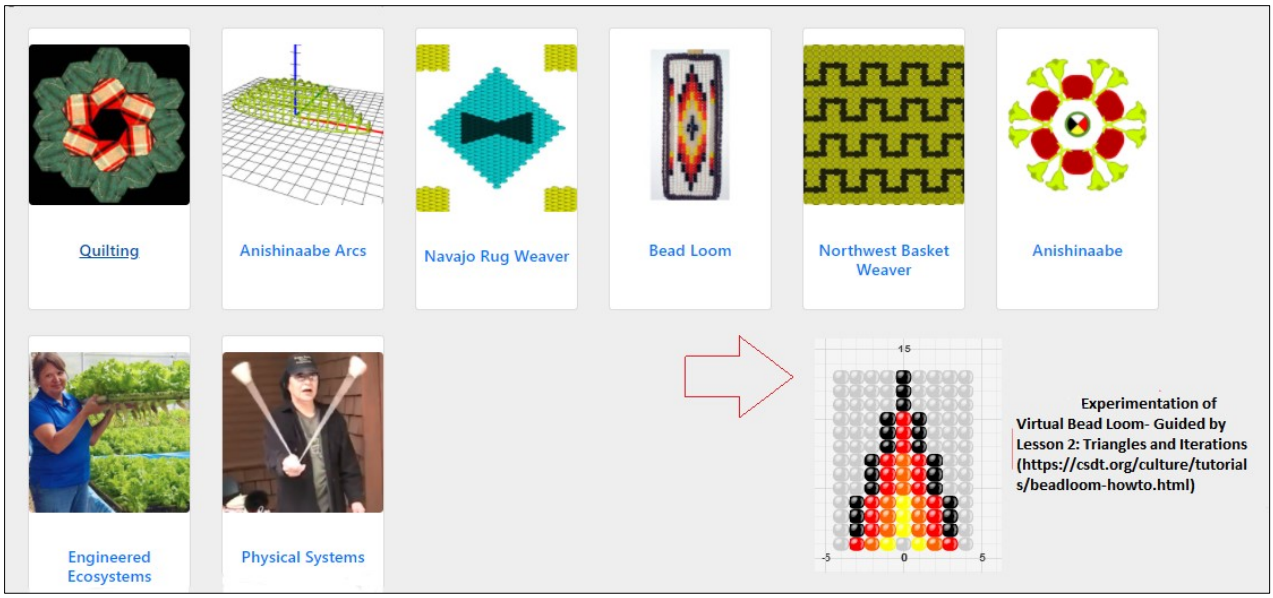

Figure [3]: CSDTs developed in collaboration with Native communities (CSDT, n.d.)

In their most recent CRC case study, Eglash et al. (2020a) presented their "generative cycle" framework with the Anishinaabe Arcs[4] (see Figure [4]). The framework is bridging between a variety of domains: "the virtual and the physical; cultural knowledge and scientific knowledge; schools and communities; and pasts and [Indigenous futurism]" (p. 1571).

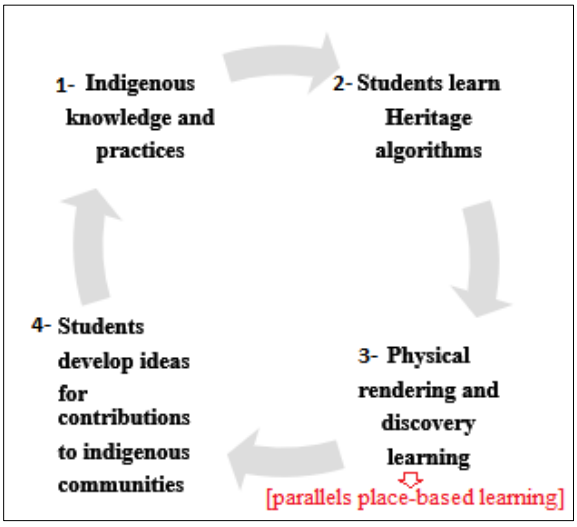

Figure [4]: The generative cycle in Anishinaabe Arcs based on (Eglash et al., 2020a)

In the application of the approach in a two-day workshop with a mix of Native and non-Native students (about half described themselves as Native American), Eglash et al. (2020a) reported

significant improvement in performance and interest. Equally important are students' statements that indicate a positive impact, for example: "*I believe my design represents the two worlds I come from. One being of my Native heritage and the other of the technology era. … This project has taught me that I can provide and give back for my people while incorporating important traditions and teachings to create a productive environment"* (Eglash et al., 2020a, p.1585).

Although CRC, along with Native American CSDTs, can be regarded as one of the most successful approaches rooted in Indigenous knowledge (especially with the new generative STEM framework). However, more changes are required in the structural design of the CSDTs. Also, more guidelines are needed in the teaching practice to ensure that the application is not merely "the sugar coating for the bad medicine of [computing]" (Eglash et al., 2020a, p.1572).

[2] Computing and community

Recently, several researchers have suggested that local community involvement in computer education may increase the likelihood that the underrepresented student groups will perceive computing as an important field to join and learn about (Lachney & Yadav, 2020; Sandoval, 2019; Pohawpatchoko, 2018). For example, Lachney and Yadav (2020) proposed a framework representing a multidirectional flow between CS educators, technologists, and cultural experts[5], where they work together in an iterative process to develop culturally responsive and computationally rich programs and products (see figure [5]). This view parallels the "community-based learning" that has shown to be beneficial for Indigenous students' learning and participation in science education (Dalbotten et al., 2014).

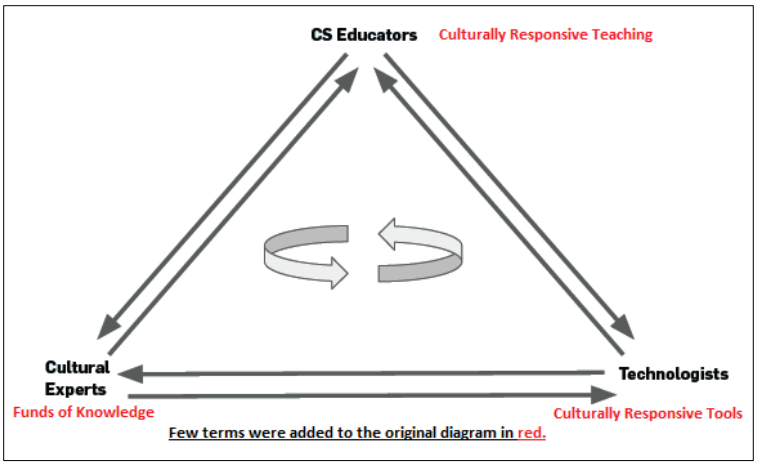

Figure [5]: A diagram presented in (Lachney & Yadav, 2020, p.21).

Pohawpatchoko, Colwell, Powell, and Lassos (2017) provide an excellent example of the impact of community involvement on Indigenous youth technological participation. The researchers found that repurposing technology into something meaningful (i.e., decolonizing the museum) not only for students, but also for local communities; the inclusion of elders and other knowledgeable tribal members; and the relationships between Indigenous staff and students, has offered the students "a sense of wholeness" (p.61), which helped bridging the divide between tradition and modernity in their lives. Indeed, the researchers who are themselves members of the community have contributed in the success of this particular case study. However, there might be instances where some cultural knowledges or practices wouldn't be shared with outsiders (especially if they are sacred to a particular community). More publications/ guidelines are needed to orient our partnership with Indigenous communities in order to ensure a "respectful contextualization" (Eglash et al., 2020a, p.1572). Also, more research is required on how to fold the community engagement back into formal education and technology design.

[3] Storytelling

Storytelling is another strategy used to support Indigenous youth computer education. Most of the literature found was based on Archibald's (2008) "Indigenous storywork", which

frames how storytelling has the power to educate and build on the seven principles of respect, responsibility, reciprocity, reverence, wholeness, interrelatedness, and synergy. Indigenous knowledge, storywork, and holistic learning practices have been used in the ANCESTOR (AborigiNal Computer Education through Storytelling) program that helps “Aboriginal” youth in British Columbia (Canada) explore computer science (Biin & Weston 2015). Another example is the game design curriculum established by Lameman, Lewis, and Fragnito (2010) for “First Nations” students in Canada, which is also based on traditional storytelling. Recently, Tzou et al. (2019) found that a family-based robotics workshop that used the stories of two families (Native-American) and focused on the meaning of place for them, opened up new ways for students to see computer programming and robotics as tools for creativity, collaboration, and cultural practices.

Except for Biin and Weston (2015), who claimed that the “worlds” feature in Alice programming offers “an effective parallel to an interconnected Indigenous world view” (p.98) and mentioned that they built specific character assets in Alice that resonate with “Aboriginal” students, none of the other researchers (who used storytelling) addressed the computational tools in use. And unfortunately, it is not clear if the Indigenous storytelling practice were impacted by the tools’ specifications or not. The only publication that focused on the impact of educational tools when using Indigenous storytelling was Litts et al. (2020). They reported cultural biases in Augmented and Interactive Storytelling (ARIS) that prevented some Native American youth from turning their nonlinear narratives into game developments (Litts et al., 2020). They suggested incorporating Indigenous knowledge more deeply into the future designs of culturally responsive computational tools (Litts et al., 2020).

[4] E-textiles

Traditional crafting and textile practices have been always part of Indigenous cultures. With this input, Kafai et al. (2014) developed their "Ethno E-textiles" program, which leverages the open-ended design affordances of existing electronic textile technologies to connect computing to the cultural practices in Native American art courses and summer camps. They reported that their program helped students translate their interests, ideas, and identities across platforms and artifacts. Mirroring this work, but with focus on the gendered differences in participation, Searle and Kafai (2015a; 2015b) have reported that e-textiles with American Native students didn't only disrupt ethnicity boundaries to computing but also the gender boundaries. The crafting elements of e-textiles allowed youth (both boys and girls) to recognize the rich technological histories of their communities and facilitated connections between home and learning spaces (Searle & Kafai, 2015a; Searle & Kafai, 2015b).

Despite the benefits, these articles discussed several challenges in practice, such as the colonial narratives about who is capable of performing CS, gendered stereotypes around practices with crafts, and the limited time of the learning experiences (Kafai et al., 2014; Searle & Kafai, 2015a; Searle & Kafai, 2015b). In addressing these barriers, the researchers suggested making links in formal schooling, connecting more with the students' communities to determine the appropriate balance between community funds of knowledge and computation, and allowing students to see how these activities can positively contribute to their communities (Kafai et al., 2014; Searle & Kafai, 2015a; Searle & Kafai, 2015b).

[5] Indigenous language being used as a programming language

Language is a fundamental component of any discussion about qualities and practices related to educating culturally healthy Indigenous students (Castagno & Brayboy, 2009). Thus, it is not possible to present a comprehensive picture of culturally responsive education in

computing without making a connection to the potential of Indigenous programming languages to enhance youth participation. Currently, Indigenous languages aren't supported in programming languages. Suppose some students attempted to use Swampy Cree syllabics[6] to simply name a function[7] in a Python[8] editor, they will likely get an error because the syntax of the programming language does not support some of the language syllabics (see figure [6]). Such elimination in the existing programming languages as well as the non-existence of Indigenous programming language embracing the Indigenous encoding paradigms widen youth's "psychological and cultural distances" (Michael, n.d.) towards the computing education and increase their thinking that "engineering and IT jobs are not in their future" (Michael, n.d.).

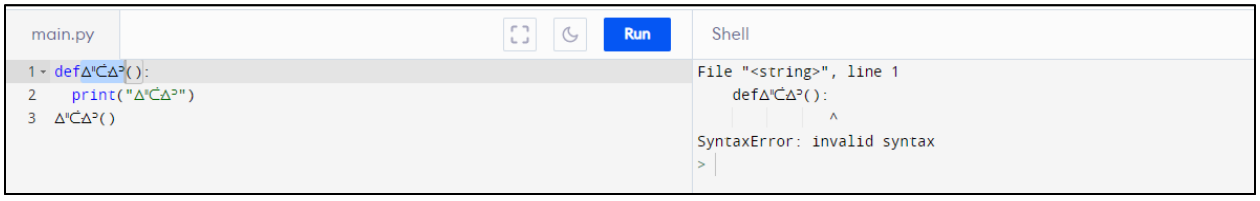

Figure [6]: Testing Cree syllabics in Python

In an effort to indigenize computer programming languages, Corbett (2018) presented his Indigenous Digital Media Toolkit (IDMT) project (i.e., currently work under process) as "the first instance of an Indigenous language being used as a programming language" (p.244) with a special interface supporting the Cree language and syllabic writing system. According to Corbett (2018), IDMT will not be a merely translated environment; instead, the programming language semantics is founded by the Indigenous worldviews and will support "the interconnectedness of living things" (p.243). This toolkit presents the possibility of creating similar environments to enhance Indigenous youth participation in the computing world.

[6] Postcolonial computing

Broadening youth's participation implies taking a critical lens at computational tools' deep structural design features (Litts et al., 2020). This process can be augmented using postcolonial computing, which provides an alternative rubric in design and analysis (Philip, Irani, & Dourish, 2012; Irani, Vertesi, Dourish, Philip, & Grinter, 2010). It prompts practitioners to question: how the cultural context shapes the design and use; the colonial systems of difference; and the premises of appropriate technology, user-centered design, participatory design, generalization, and more (Philip et al., 2012; Irani et al. 2010). The "tactics" of postcolonial computing are crucial for enacting more proper means in the "hybridization" process, situating the Indigenous and Western sciences as equals in design and development (Philip et al., 2012).

Conclusion

The literature paints a clear picture of the importance and value of Indigenous ways of knowing if we want to see a new generation of Indigenous technologists and develop equity-oriented computing education. The work cited above also shows the possibility for Indigenous knowledge to work in concert rather than in conflict, within computing settings striving to support both views. Understanding the non-computational issues that led to Indigenous students' disengagement in the first place, engaging Indigenous communities in the teaching processes, and helping students to see the relationships between computing and the applications and needs within their communities, are all important aspects required while integrating Indigenous ways of knowing in the classroom. There are also other requirements in the design of learning technologies. Firstly, there is a need to foster the collaboration between localized Indigenous knowledge experts and computing practitioners. Secondly, we must address the biases at the deeper structural level, the epistemological foundations of our tools. As such, there is a need "to

expand who designs in the first place" (Litts et al., 2020, p.853). Thirdly, it is essential to escalate the Indigenous knowledges and languages into the roots of computing, which are the programming languages themselves (i.e., indigenization of the programming languages). Lastly, we need to move from the development discourse to postcolonial discourse, centered on questioning power, participation, and accessibility aspects in the cultural-technical practices (Philips et al., 2012).

In closing, I acknowledge that understanding and integrating a different culture and its ways of knowing, especially in light of the vast depths of Indigenous knowledge, is not easy and can be a deterrent for non-Indigenous educators and technologists. But let us be willing to overcome the challenges and create a bridge to learn from each other. The Indigenous ways of knowing can benefit all students, Indigenous or non-Indigenous alike. We may also approach alternative visions in our field towards a just and sustainable future (Eglash et al., 2020b).

Notes

[1] Computing is a field of study that encompasses computer science, computer engineering, information science and information technology.

[2] Throughout this paper, I use “Indigenous” to refer to some common characteristics among Indigenous peoples- this while acknowledging that the Indigenous experience is not the same (Smith, 1999). Other terms in use correspond the original references.

[3] I am an outsider (non-Indigenous Canadian computer engineer). My learning was only facilitated through Etec521 course material and the literature addressing the project topic.

[4] Anishinaabe Arcs CDST design allows students to create 3D interactive structures based on wigwams, canoe ribs, baskets, and other heritage algorithms (Eglash et al., 2020a).

[5] Cultural experts include elders, artists, scholars, and other representatives of the community.

[6] Characters used in the code example are from Wikipedia (2021, July).

[7] Function is a collection of statements to perform a specific task in programming.

[8] Python is one of the most popular programming languages used for teaching coding to novice students.

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