frontiers | Frontiers in Education

TYPE Perspective
PUBLISHED 01 December 2022
DOI 10.3389/feduc.2022.1055722

OPEN ACCESS

EDITED BY
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SPECIALTY SECTION
This article was submitted to
STEM Education,
a section of the journal
Frontiers in Education

RECEIVED 28 September 2022
ACCEPTED 31 October 2022
PUBLISHED 01 December 2022

CITATION
Avendano-Uribe BE, Ojeda-Ramírez S
and Perez-Baron J (2022)
Resourcefulness, narratives,
and identity in science, technology,
engineering, arts and mathematics
education: A perspective
of makerspaces for rural communities
in Colombia.
Front. Educ. 7:1055722.
doi: 10.3389/feduc.2022.1055722

Resourcefulness, narratives, and identity in science, technology, engineering, arts and mathematics education: A perspective of makerspaces for rural communities in Colombia

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Disparities of scientific education (STEM) in rural and remote communities are exacerbating inequalities and taking away opportunities for youth to explore their scientific interests and participate in science-making globally. Maker education in rural and remote areas of Latin America could boost the participation of rural communities in scientific education and open alternatives to the lack of higher literacy rates and STEM education. In Colombia, tertiary education has been making efforts to close this gap through the Itinerant Technical Academies of Servicio Nacional de Aprendizaje (SENA: National Learning Service). Participants in the Technical Academies create relevant technologies for their context, reflecting on their cultural values and aesthetics. In this contribution, we describe three projects conducted in the itinerant Technical Academies of rural Colombia in Narino to exemplify how participants made their artifacts relevant to their culture using available resources, materials, and practices. Students are using available resources to create artifacts that are relevant to their social contexts and aligned with constructivist practices. We propose and discuss three characteristics that have emerged in makerspaces situated in rural Colombia: (i) Narratives, (ii) Resourcefulness, and (iii) Identities and we suggest that makers, scholars, policymakers, and educators should pay attention to those three elements to guide future studies and further research on maker education in the Global South.

KEYWORDS

educational policy, makerspaces, rural education, Colombian education system, STEAM education, identity, narratives, resourcefulness

Introduction

The Maker Movement, a grassroot culture dedicated to hands-on making and technological innovation has infiltrated the educational enterprise globally, gaining attention of both researchers and educators interested in how people learn through making (Peppler et al., 2016). The maker movement has entered Latin America through different spaces for technological exploration and fabrication such as *fablabs*, *hackerspaces*, and *makerspaces* (Stacey, 2014). In particular, Makerspaces are informal sites for creative production in art, science, technology, and engineering where people of all ages blend digital and physical technologies to explore ideas, learn technical skills, and create new products (Sheridan et al., 2014). In the context of "creative cities," the creation of *makerspaces* and *fablabs* has become part of the public policy of Latin American cities such as São Paulo and Bogota (Sperling et al., 2015). Nevertheless, the inclusion of makerspaces in rural Latin America has not yet received much attention from either policy makers or researchers.

Colombia is a multicultural country with great economic disparities, spatial divides, and other markers of disadvantage that reinforce educational inequalities (OECD, 2016; World Bank, 2021; Avendano-Uribe et al., 2022). Moreover, children living in rural areas have less access to education than in urban centers. Compared to students in urban centers, populations in rural areas receive fewer years of schooling (MEN, 2015) and have lower school enrolment and higher illiteracy rates (DANE, 2018). In Latin America, the lack of exposure to STEM education in rural and remote communities is exacerbating inequalities and taking away opportunities for youth to explore their scientific interests and participate in science-making nationwide and globally (Avendano-Uribe et al., 2022).

It has been shown that grassroots science, technology, engineering, arts and mathematics (STEAM) (STEM + Arts) programs could be boosted by makerspaces, as they constitute communities of practice for hands-on tinkering with STEM tools and practices that could be brought to rural settings (Barniskis, 2014). In addition, Maker Education fosters community engagement in the production of artifacts for their daily lives (Halverson and Sheridan, 2014). For makerspaces to be fully leveraged as opportunities to foster STEAM education in rural Colombia, it is important to acknowledge how Maker education in the Global North dialogs with practices and strategies in the Global South. In Latin American makerspaces, a strong global accent based on technological innovations such as 3D printing and electronics toolkits, is sharing space with initiatives with a local accent based on the technological, cultural, and social reality of the regions (Sperling et al., 2015). However, Maker Spaces in Latin America are growing in unknown numbers (Sperling et al., 2015), and are facing challenges due to limited access to materials, technologies, and equipment for remote communities.

In this contribution, we present our perspective of Colombian rural Maker Education, to describe an example of the current state of makerspaces in the context of the rural Global South. We describe three projects conducted in the itinerant Technical Academies of rural Colombia (ITA) Narino to exemplify how participants made their artifacts that are relevant to their rural contexts and communities using available resources, materials, and practices. We propose and discuss three characteristics that have emerged in makerspaces situated in rural Colombia: (i) Narratives, (ii) Resourcefulness, and (iii) Identities, and we suggest that makers, scholars, policymakers, and educators should pay attention to those three elements to guide future studies and further research on Maker Education in the Global South.

State of the art: Colombian technical academies as maker spaces

The tertiary educational system in Colombia, known as the National System of Tertiary Education (SNET), includes two degrees of complexity: Universities and technical training. According to the Ministry of Education in Colombia, there are 366 technical education institutions registered in the national system (Fonseca and Vargas, 2016). The National Service Learning or SENA (Spanish short for Servicio Nacional de Aprendizaje), counts 117 centers in 33 regional sites (SENA, 2022). One of the non-formal educational programs in SENA is Itinerant Technical Academy that travels from place to place in rural and remote areas of Colombia (Ochoa-Rojas, 2021). Itinerant Technical academies are capacity-building STEAM programs directed at young people in rural areas of Colombia. The program aims to foster technological-based education to create, collaborate, and communicate local-based solutions for rural challenges of the country (Solís-Molina et al., 2017). In particular, the Itinerant Technical Academy Narino, was created in 2020 as part of the South Colombian International Centre for Logistics, Regional Narino (SENA, 2022).

Students of the itinerant technical academies socialize and share common interests around problems that their communities are facing to design and create artifacts that resonate with their culture. According to the definition of Makerspaces presented by Sheridan et al. (2014), Itinerant Technical Academies can be considered Makerspaces, as they are sites for creative production where participants work independently or collaboratively in a studio, workshop or learning environment with materials to design and make things (Halverson and Sheridan, 2014). Regarding teaching, instructors of Technical Academies use demonstrative-instructions that foster open-ended challenges to explore how the design process can support students' learning of physics, engineering, chemistry concepts and general knowledge in

science, technology, engineering, arts, mathematics, and humanities (STEAM+) (Kolodner et al., 2003; Sheridan et al., 2014).

An example of Technical Academies as makerspaces is Itinerant Narino's Technical Academy, which aims to contribute to promoting STEAM skills and a culture that values science, technology, and innovation as part of social transformation in the local communities. Participants of Narino's Technical Academy are mainly secondary school students accompanied by professional trainers or instructors. Participation happens after school through informal and extracurricular activities. Up to date, there are more than 3,378 students from 60 rural schools distributed in small groups (less than 15 participants) coming from 30 municipalities of Narino, including remote and unprivileged areas like Tumaco, and Ipiales (details in **Supplementary Table 1**). Both teachers in their schools and mentors in the Technical Academy are constantly in communication and monitoring the academic achievement and skills improvements of students participating in the courses.

Moreover, participants of the Itinerant Technical Academies create relevant technologies for their context, reflecting on their cultural values and aesthetics. For example, Franco et al. (2019) described the club "Cunning STEM: From play to wit." This club is about science entrepreneurship around the most common social, infrastructure, economic, and ecological issues of the local community in Tuquerres, Narino using robotics, proposing solutions to problems of their context (Franco et al., 2019). Students have participated in regional, national, and international science fairs and there are more than 33 scientific journal publications, 10% of which are peer-reviewed scientific papers. In particular, one of their successful projects: "Hand-made solar cells" reported by Restrepo et al. (2022) concluded that in their results "cells were obtained in a very easy and economical manner from Diacol Capiro potato" which is a locally adapted solution using agricultural/native products from the region. This work also reported "new laboratory practices to explain the generation of clean energy, and because of the simplicity of this work the students (high school level) were able to develop all the procedures without any difficulty and having a better understanding of the generation of clean energy" (Restrepo et al., 2022).

Our perspective: Three elements of rural Colombia makerspaces

Maker education has been implemented globally, but the execution and research of maker education in the Global South have been shown to have distinct characteristics, such as interest for urgent and local issues, as well as a need for openness to different worldviews, aiming to broad participation in these spaces (Seo-Zindy and Heeks, 2017; Abbassi et al., 2022). Our perspective consists of three elements that we have found in Makerspaces in Colombia: Resourcefulness, Narratives, and Identities. This perspective might suggest a preliminary understanding of the characteristics of Maker Education in Colombia, and open questions for other settings in Latin America and the Global South.

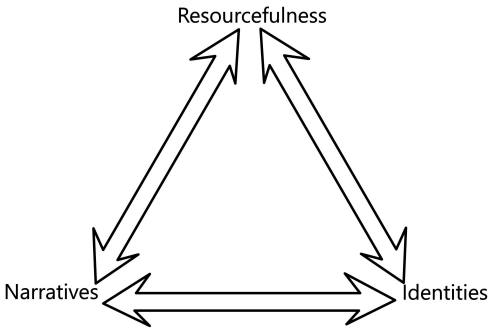

FIGURE 1
Elements of rural Colombian maker education.

Through the identification of these three elements in three different projects made by three different groups of students in the Technical Academies, especifically from Narino's Itinerant Technical Academy, we aim to show how they reflect our perspective of Makerspace in rural areas of Colombia. We use **Figure 1** to foreground the emergent elements we have found in students projects of Technical Academies and describe how they are related to each other. This diagram summarizes emerging elements that we have seen in TA, and that we consider could guide future makerspaces in the rural Global South.

In **Figure 1**, we identify three main elements that were present and paramount in the Technical Academies: Resourcefulness, Narratives, and Identity.

Resourcefulness

Based on Sheridan and Konopasky (2016) we define resourcefulness as individual or communal acts of innovating drawing on internal sources such as skills, knowledge, and confidence or external sources such as experts, informational texts, community partners, and, in these cases, available materials, and cultural traditions. The resources are also spaces and factors in the environment that support and safeguard learning (Sheridan and Konopasky, 2016).

Since STEAM education in Latin America is still incipient (Cabello et al., 2021), and with countries like Colombia being one of the most unequal (World Bank, 2021), resourcefulness rises as a virtue. Resourcefulness in these makerspaces has been shown to open pathways for making and digital fabrication in communities where access to technology is limited. By leveraging the available resources, these makerspaces adapt global trends of digital fabrications or specifics uses of materials,

such as 3D printing, to resources that are available in the local context. Our perspective contemplates resourcefulness as a possibility for emerging disruptive artifacts, that include materials and technologies available locally with overarching technologies that are used in makerspaces globally (Sperling et al., 2015).

Narratives

As well as technical academies are geographically situated in rural communities, in Colombia, these makerspaces can also be situated in paramount socio-historical moments in time. With access to technology and education oscillating due to situations such as COVID-19 or the recent implementation of the peace process (Torres Madroñero et al., 2021), it is not surprising that students find their making projects as opportunities to dialog with narratives relevant to their communities. On this, we have found that making video games that propose new stories about Colombian Independence, aligns with the concept of "restorying," theorized as a process by which people reshape narratives to represent a diversity of perspectives and experiences that are often missing or silenced in mainstream texts, media, and popular discourse (Thomas and Stornaiuolo, 2016). "Restorying" has already been used to understand how youth use computing to develop counter-narratives (Shaw et al., 2021), and we think makerspaces such as these are explicitly or implicitly related to "restorying practices," in which the students are authors of counter-stories and also create new narratives for existing materials.

Identity

The final element we found in the maker projects we describe is Identity, as students author identities and modes of belonging to their communities through making in these makerspaces. We define identity as ways in which students participate in communities of practice (Wenger, 1998; Stets and Burke, 2000), and we acknowledge identity formation is dynamic, negotiated, and constructed through social interactions (Holland et al., 1998; Wenger, 1998). Here, we highlight cultural identity arising from one's cultural groups memberships, and identification with local and non-western and traditional forms of knowledge, practices, and expertises that arose locally in the rural communities and that may not reflect technologies or practices used globally. Shaw and Kafai (2020), building on Moje and Luke (2009), charted different metaphors for identity with computing, or ways in which students use computing to express their identities. Likewise, we think some of those metaphors, such as Identity as community critic and Identity as "restorying" can be addressed through makerspaces in rural communities, as the projects we describe seek to reshape stories or to use materials that are abundant in the communities to improve people's life and access to technologies, such as the water filter and the recycled 3D printer. Likewise, identity as interest connections, or in this case, identity as cultural connections, was explored in the maker projects by leveraging the use of materials such as coconut and shells, which have specific cultural connotations in the communities of Narino.

Resourcefulness, narratives, and identity in maker projects of technical academies

We show three projects of students that are an example of constructionist learning in a makerspace and we identify elements in every project in which students include components that are relevant to their communities and their cultures (**Figure 2**). The first example is a 3D printer made by two students in the municipality of La Cruz, Narino–Colombia that consisted in making a low-cost 3D printer re-utilizing CD-ROM drive, the second example is a digital video game based on Colombia's history of independence and the third one was a water filter made with coconut fiber and seashells.

Resourcefulness in maker projects

As makerspaces, the itinerant technical academies include in their making materials many of the resources that are abundant in the region, as well as e-residues that could be used to tinker and create. In the low-cost 3D printer project, students used the pieces of dismantled CD-ROM drives. Students stated that they used these recycled materials due to the necessity of the 3D printer being low-cost, and at the same time, to re-utilize materials that otherwise would be disposed of and become toxic waste. A relationship between necessity, ingenuity, and recycling has been previously observed in the Global South; for example, using e-waste scavenging as a living strategy in Ghana (Oteng-Ababio, 2012).

Another example is the use of seashells and coconut fiber, otherwise food residues or raw unused materials, for the making of artifacts that could be relevant to the community, such as an artifact for a water filter. This project has been described by one of the instructors as "leveraging the conditions and the raw materials that are present here, in the municipality of Tumaco, Narino–Colombia." Likewise, a student of the makerspace said they were "leveraging the residues of the local gastronomy for the making of a filter." The instructor also said that the filter is intended to improve the water quality for human consumption in the municipality of Tumaco. Therefore, students are using available resources to create artifacts that are relevant to their social contexts, aligned with constructionist practices. The use of coconut fiber is especially remarkable, as coconut is an abundant raw material in the location of the makerspace. Here, the resourcefulness evidenced in the makerspace can connect

FIGURE 2
(A) Artifact: coconut filter, **(B)** low-cost 3D printer, **(C)** independency video game (SENA, 2022).

with practices such as Bio-design, or the incorporation of living organisms and biological materials in design (Denend, 2015). This resourcefulness, through our perspective, can be translated into further explorations of materials and practices that can be further explored through making education in the Global South, such as making with recycled and reused e-materials, bio-design and, with further inclusion and manipulation of living organisms, makerspaces in the Global South could be a great setting to explore and include bio-making.

Narratives in maker projects

We identify two forms in which narratives and histories are included in maker projects: the first one, is that makers recognize and reshape the histories of materials by recycling them and reusing them, and the second one is restorying history. By using coconut fiber and seashells to filter water, students are recognizing the past histories of these materials, used previously with gastronomical purposes, and re-utilize them in the makerspace to make an artifact with social relevance. Likewise, with the CD-ROM Drive, students are repurposing an object with a history, and they are finding a new use/application for it. While making these artifacts, students are not only engaging in making processes, but they are also authoring new stories for these materials. The use of biological materials for making dialogs with fields such as bio-design and bio-making, even when the materials, in this case, are no longer alive.

On the other hand, the independentist video game uses a clear reference to Colombian history, and constituted a media product, in which students used different modalities to tell a story and convey ideals. In the game, a retelling of the independence story is stated by imagining an indigenous royal commander from the XVII century, Agustin Agualongo, answering to Simón Bolivar: "We don't want your independence! That fight won't give us freedom, the power will only pass to the hands of the "Criollos" (Mixed raced, half Spaniards, and half indigenous) and now the people will be subjected and dominated by you. The separation (from Spain Crown) will only bring us devastation, the blood of my people will be spilled, children will become orphans, and fear and suffering will be felt." This a clear reference to a history in which ethnical and racial minorities have been excluded from power and discourse and is also a counter narrative to the traditional history of independence that has been through in Colombia. The fact that children from Nariño, a department with an abundant demographic of these groups, are using makerspaces to make and design videogames that tell the stories of their ancestors is remarkable; and a clear example of the presence of histories and restorying through makerspaces.

Identities in maker projects

There are many ways in which students of the makerspaces have been addressing their identity in the itinerant technical

academies. Here, we describe ways in which different metaphors can be used to read student's identities through their makerspace's projects. First, it was prevalent how students developed their identity as community critics in the makerspace projects. In the low-cost 3D printer project, for example, students clearly identify how future members of the community, in the makerspace, could benefit from having a 3D printer that is accessible and can be used by everybody. The necessities of the community are identified in the water filter project, as students talked about the necessity of clean and drinkable water in their community. In these two projects, there is a call for reusing and recycling materials based on not producing environmental damage to the community's natural surroundings. This sense of belonging and the use of makerspaces to create artifacts that directly benefit the community reflects on principles such as Ubuntu, I am because we are, which have had a cultural resonance in the Colombian pacific region during recent years (Mina Rojas et al., 2015).

Regarding leveraging cultural identity and sense of belonging, the independentist video game explicitly calls for a representation of minoritized communities. As it is said by one of the characters in the game: "Mr. Bolivar: Us, Indigenous, Blacks, and Spaniard live together in Narino in a wise manner.", and by one of the students of the makerspace: "We wanted to rescue identities that have been lost, a culture that has stayed only on books." Students used the making and design of video games as a medium to represent and share their ethnic and cultural identities. Likewise, by using coconut fiber as a water filter, students are connecting with maker practices that are traditional to their land and cultures, since coconut has been used for the making of handcrafts and cultural artifacts in the region, not to mention its paramount influence in the economy and the culinary culture. Similarly, the use of seashells connects with the ancient and traditional use of seashells as a currency of the Tumaco–Tolita indigenous people who inhabited the region (Corradine Mora, 2005). Using materials such as coconut and seashells in makerspaces is not only a matter of resourcefulness but also a reflection of the cultural identity of the region where the makerspaces took place.

Discussion

Practices and learning of the Maker Education in the Global South differ from the maker education in the Global North. We found three characteristics of makerspaces in Colombia that could be echoed in maker education initiatives in the Global South. Our perspective, based on the experience of rural Narino's Technical Academy as a makerspace, aims to amplify current literature on Maker Education in Latin America, led by Maker Education happening in Brazilian and Colombian metropolises, Sao Paulo and Bogota respectively, as creative cities in the region (Sperling et al., 2015). In Colombia, rural Maker Education is taking place in the remote areas of the country, regions with multiple disparities and socioeconomic challenges, exacerbating autochthonous properties of Maker learning that impacts STEAM educational systems in Latin America (Avendano-Uribe et al., 2022).

In our perspective, we identify three characteristics of rural makerspaces in Colombia that could align and enrich maker experiences in the Global South. Being open to the inclusion of resourcefulness, narratives, and identities in makerspaces can strengthen culture in rural Colombia as well as in other settings in the Global South. Vulnerable, underrepresented, and under-educated communities have access to Makerspaces seeking practical and hands-on education to solve their day-by-day challenges, seeking entertainment, or even seek entrepreneurship (Smith, 2017; Reynaga-Peña et al., 2020; Gillespie et al., 2021). We find that by doing this they often include resourcefulness, narratives, and identity in their maker learning practices.

Our perspective could be useful to scholars, makerspaces educators, and policymakers. Scholar work on makerspaces in the Global South may find how these characteristics; narrative, resourcefulness, and identity, are present in makerspaces, and might complement theoretical frameworks used to analyze Maker Education in the Global South. Likewise, educators could use our perspective to invite their students to leverage resourcefulness, narratives, and identities through the making of their artifacts, using students' lives, stories, cultures, and environments as inputs. We also call for more attention from policymakers to the itinerant Technical Academies (ITA) in Narino–Colombia and other SENA ITA in Colombia, as paramount learning processes from rural and remote communities which is theoretically rich for Maker Education Scholars and practically relevant for other rural communities in the Global South. We argue that, as living makerspaces, the model of ITA at National Learning Service -SENA is worth replicating in other settings of Latin America or the Global South.

Finally, formal scholarship studying Colombian makerspaces, whether in the form of ITA or not, is needed. In our exploration, we found emerging elements of maker education in rural Colombia, and we suggest that exploring how these elements are portrayed in other geographies and contexts can illuminate how maker education in the Global South is incorporating resourcefulness, narratives, and identities. We encourage researchers to continue studying elements that explain Maker Education and how the Global South is dialoguing with the global-scale maker movement.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Written informed consent was obtained from the minor(s)' legal guardian/next of kin for the publication of any potentially identifiable images or data included in this manuscript.

Author contributions

BA-U and SO-R contributed to the same percentage of academic insights, conception of the idea, and wrote all sections. JP-B collected the data and provided insights on sections 2. All authors contributed to the article and approved the submitted version.

Funding

This study was possible thanks to the generous help of the University of California, Irvine, through the Miguel Vélez scholarship awarded to the author and the University of Canterbury Library Open Access fund.

Acknowledgments

Profound gratitude to Dr. Andres Lombana-Bermudez at Universidad Javeriana in Bogotá, Colombia for his valuable input while writing the manuscript. ScienteLab and the team of Science Clubs Colombia who are working to close the gap between rural and urban scientific education. Thanks to the Itinerant Technical Academies of Narino and his team in SENA who believe in the potential of students to achieve high quality scientific education in Colombia, specifically thanks to SENA general headquarters, SENA regional Narino, the system for research, technology, and innovation SENNOVA, and the great job that Itinerant Technical Academies in Centro Sur Colombiano de Logística Internacional SENA who allow authors of this manuscript to disseminate the work they are doing. We thank the students and instructors who directly participated in the three example projects described in this research: Video Game: Juan Bravo, Santiago Aguirre, Diego Andrés, Melany Orbes, Camilo Caipe, Jesús Escobar. Authors of 3D printing project: Samuel Rosero, Dayana Realpe's, Coconut filter: María Portocarrero, Karen Bernal, Juan Araujo, Elkin Palacios. Finally, we acknowledge organizations, governments agencies and people indirectly involved in the three example projects we are describing in this research: Government of Nariño (2012–2015 and 2020–2023), Tuquerres Mayor (2012–2015 and 2020–2023), Educational Institutions and Schools of the Department of Nariño who has been involved in the training processes conducted by Itinerant Technical Academies (IE Genaro León Guachucal, IE Normal Superior del Mayo. La Cruz Nariño, IE Ciudadela Mixta Colombia. Tumaco Nariño, IE Genaro León Guachucal). We acknowledge the people who have believed and contributed to the development of Itinerant Technical Academies: Sara Arturo, Libia Ramírez, Milton Mora, Jhon Cabrera, Juan López, Raúl Delgado, Paulo Rodríguez, Diana Sarmiento. Jorge Tobar, Erika Sánchez, Mauricio Flórez, Andrés Acevedo, Amanda Vélez, Diana Potosí, Harold Muñoz, Jesús Díaz, Miguel Ramírez, Lorena Guerrero, Claudia Zambrano, Juan Timaran, Hermes Cuastumal.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2022.1055722/full#supplementary-material

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