Introducing technology into learning designs for indigenous contexts

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Abstract. Technology is more pervasive, and it has reached indigenous communities. This paper presents a qualitative study and reflects on three learning designs that integrate information and communication technologies (ICT) in the context of an indigenous school in Peru. This paper demonstrates that indigenous people, rather than being mere users of technology, could create and design technology to their own benefit by integrating their own worldviews, ancestral knowledge, and ways of learning. It is shown that new approaches are necessary to implement learning designs that are open, flexible, and have partnership with community elders, where technology plays several key roles as a tool, as a process, as a type of knowledge and as a set of values.

Keywords: technology, learning designs, indigenous knowledge, information and communication technologies (ICT), informal learning environments

1 Introduction

The new technologies are impacting our lives and transforming us. Their influence goes beyond simple operational interactions, and we are being changed deeply and unconsciously by them. Thus, one of the biggest impacts of technology is on indigenous people who previously could not be reached by most of the advances, progress, and discoveries of sciences and technology [1]. However, digital technologies are becoming pervasive and ubiquitous around the world and are being introduced at a fast pace even in isolated communities [2]. One important area that is being challenged by technology is formal education, because it still uses traditional methods of instruction, using a top-down approach that usually does not fit indigenous contexts, needs, and knowledge [3].

This paper focuses on the role of technology introduced into learning designs in indigenous contexts. It starts by reviewing the literature on technology and indigenous knowledge, followed by the methodology of the study. Then, it provides the background of a particular indigenous school in Peru. Afterward, three case examples that describe technology's significant roles and the learning designs carried out during the study are explained. Next, discussions are given on different pedagogical approaches, learning styles, and settings, as well as how technology plays different roles in the learning designs. Finally, a conclusion highlights the important points of this work.

2 Technology and indigenous knowledge

Technology is about "human innovation in action" [4]. It consists of the knowledge, processes, and resources needed to develop systems to solve problems and extend human capabilities. Nowadays, the new technologies – especially digital technologies – are developing very fast and are transforming our societies. They are ubiquitous and can be found even in remote places [5]. Over time, technology has transformed how people live and perceive the world. New tools and devices have continually brought changes to human societies (e.g., hunter-gatherer, agricultural, industrial, digital) throughout history and have impacted their economy, communication, and culture [6].

2.1 Ways of conceptualizing technology

Although there are many ways to conceptualize technology, one interesting perspective is highlighted by de Vries [7], who used Mitcham's [8] structure to conceptualize technology in four different ways: (a) as an artifact, (b) as knowledge, (c) as an activity, and (d) as a set of values. *As an artifact or product,* technology could be associated with a concrete artifact or object (e.g., a laptop, a mobile phone). It is important to highlight that technology as an artifact functions according to the social context. *As knowledge or abstract artifact***,** technology is the knowledge itself. In a way, it is an abstract artifact (e.g., a language, a software, a set of skills). *As an activity or process,* processes and activities are recognized as technology. In that sense, technology is dynamic and rapidly evolving that transforms our world through manual, mechanical or automated procedures. *As a set of values*, technology is connected to a worldview and culture, which is relevant when dealing with social matters. These conceptualizations are helpful in understanding the importance and impact of technology in the lives of indigenous people.

2.2 Information and communication technologies (ICT)

Information and communication technologies (ICT) are defined as a "diverse set of technological tools and resources to communicate, create, disseminate, store and manage information" [9]. ICT includes not only computers, the internet, and mobile phones, but also radio, television, and the equipment and services associated with these and other technologies. Thus, ICT is a broad term that emphasizes the use of technology in a wide range of fields, such as education, health, transportation, and business. Moreover, ICT is a highly flexible tool that can be adapted and which offers communication, collaboration, and new ways of learning [10].

Since the end of the last century, there has been an increasing interest in introducing and integrating ICT into schools to support the learning designs implemented in classrooms. ICT gives students access to information; it also has the potential to change the nature of the learning process and the pedagogy. More importantly, it gives learners the opportunity of being part of a connected society [11].

2.3 Indigenous knowledge and education

Indigenous knowledge is defined as the knowledge that was instrumental in the adaptation of indigenous people to their biophysical environment [12]. Indigenous people are those people who have inhabited a territory since ancestral times and who share a common history, language, and culture that distinguish them from other people [13]. It is important to mention that indigenous people around the world have their own worldviews embedded in their culture and ways of life [14] [15]. Their ancestral knowledge has been maintained mostly through oral traditions [16]. This knowledge is adaptive, sustainable, and specific to each group's culture and location [17]. Indigenous people have close links with nature and have adapted to life in difficult geographic locations (e.g., the Amazon, the Himalayas, the Sahara). Thus, they have particular and significant knowledge of their natural environments, which has helped them to continue living and striving for millennia [18] [19]. However, indigenous knowledge lacks systematic documentation, and it is not integrated into formal education [17] [20].

For example, in Peru and Bolivia, the Aymara people have ancient principles for living well (*sumac qamaña*), valuing their own language, culture, world perspective, and spirituality [15]. The Quandamooka people of Australia have a similar worldview and knowledge articulated through ways of knowing, ways of being, and ways of doing [14]. Despite the importance of indigenous knowledge, it still lacks recognition and acceptance in education systems around the world. Thus, indigenous people are not being given an equitable and sustainable education [21].

2.4 ICT in learning designs that incorporate indigenous knowledge

A learning design is a framework used to describe learning environments and learning activities [22]. A learning design helps practitioners to implement appropriate learning experiences based on pedagogical principles (e.g., constructionism). Using ICT in learning designs offers diverse opportunities for indigenous learners to include their specific experiences and worldviews in their education. Thus, ICT could enhance indigenous knowledge and connect it to the world [23]. Mobile devices also support diverse scenarios for learning (e.g., learning outside of formal settings) and allow indigenous people to learn at home, in natural environments, and within the rural community [24] [25], as they have a holistic way of learning [26] [27]. Interestingly, ICT tools also support oral interactions using audio-visual technologies [17], which fits well with the fundamental oral communication of indigenous people. ICT has the potential to be used to support new pedagogical approaches [28].

In addition, indigenous learners can evolve from mere users of technology to active creators and producers of technology [29] [30]. When promoting ICT access to indigenous people, it is necessary to address their specific needs by providing equitable ICT access to rural locations [31] by ensuring that the digital resources provided are culturally appropriate [32].

3 Methodology

This qualitative study explores three case examples of learning designs that use technology to support indigenous children's learning. The study was carried out in the form of after-school activities in the rural primary school No. 70678, located in the Aymara community of Huilasipe. The researcher is from that region. Her grandmother and other relatives belong to that ethnic group.

The methodology employed was design-based research (DBR), which allows the researcher to study how learning happens in natural settings for the explicit purpose of producing changes that lead to better learning [33] [34]. Thus, the learning designs were developed using the principles of Papert's constructionism that underpin the design of learning environments where learners engage in open, flexible and meaningful hands-on activities based on their own interests and motivations [35].

The researcher was a participant observer and collaborated as a temporary volunteer teacher in the school's activities. Prior to initiating the study, informed consent for children's participation was obtained from their parents/guardians. Data was collected through observations, interviews, photographs, and children's work or artifacts. The participants in the study were children who volunteered to participate and spend extra time in learning activities that integrated technology.

4 Practical experiences in the field

4.1 Background

In 2005, the One Laptop per Child (OLPC) project was announced by Nicolas Negroponte from the Massachusetts Institute of Technology (MIT). Its goal is to provide low-cost XO laptops to children, especially in developing countries [36]. The XO acronym comes from the project's logo, which depicts a person's body as an "X" with an "O" on top for the head. Constructionism was its pedagogical approach, developed by Seymour Papert [35], who also belonged to the Media Lab at MIT.

In Peru, approximately 850,000 XO laptops have been distributed by the Ministry of Education [37]. The main objective of the program is to provide the poorest students in faraway places with access to technology [38].

One ethnic group that received the XO laptops was the Aymara people. They are mainly located to the South of the Peruvian Andes, around Lake Titicaca. Their main economic activities are agriculture and herding sheep and cattle. Their values are related to respecting Mother Earth (*Pachamama*) and having reciprocity with others [39]. The Aymara community of Huilasipe is composed of approximately 200 members. Through the OLPC project, its rural school No. 70678 was provided with 70 XO laptops, which included open-source digital resources. The school was also given two LEGO® WeDo robotics kits [40]. The school has approximately 40 students from the first grade to the sixth grade. The community and the school have an energy supply but no access to television or the internet. The community uses radios as its primary means of communication.

4.2 Three case examples of learning designs

The literature mentions that there is a limited knowledge on how ICT is embedded in learning designs and practices; there is a lack of description of the procedures that have been implemented, in order to reproduce them in other contexts [41] [42] [43].

Therefore, this study presents three representative case examples of using ICT in learning designs for indigenous children. The learning designs were flexible and could be changed according to the learners' needs in an informal learning environment. The case examples were selected based on the different pedagogical approaches employed, the use of different technologies, and the different settings or spaces used for learning. The case examples are (a) self-directed learning and out-of-school exploration using the XO laptop, (b) documenting indigenous knowledge about healing plants, and (c) a robotics project to demonstrate how to protect crops from frost.

Table 1. Learning design that includes self-directed learning.

Title	Tinkering with and exploring my XO laptop
Purpose	Knowing how the software of the XO laptop works.
Learning outcomes	LO1: Identify functions of the software included in the XO laptop. LO2: Use and operate the XO laptop. LO3: Share new discoveries with others.
Learning activities or procedure	• Learners receive their laptops and start tinkering with them during their spare time at home or outdoors, guided by some initial and personal questions: - *What kind of things can I do with this laptop?* - *What interesting things does the software allow me to do?* • Discovering special characteristics of the laptop through trial and error. • Sharing discoveries with friends.
Materials or resources	• XO laptop and its digital open-source software applications.
Setting	• Informal learning environment: learners' homes, in their spare time.

Case example A: Self-directed learning and out-of-school exploration using the XO laptop. This learning design was initiated and carried out by a ten-year-old indigenous boy in the fourth-grade who had a natural curiosity about exploring the XO laptop. The researcher visited the boy's family and observed that he was always tinkering with his laptop. Through trial and error, the boy taught himself how to use the software included on the XO laptop. For example, he discovered an 'Easter egg' (a surprise hidden in the software by its developer) that nobody was aware of, including official government trainers. This learning design could be considered a kind of self-directed learning without any teacher or adult involvement. The boy interacted assiduously with his laptop and learned how to use the software. He also shared his discoveries with his friends at school. Moreover, he demonstrated that he

could dismantle and rebuild other devices such as bicycles and radios. Table 1 displays the learning design that describes the boy's self-directed learning.

Fig. 1. Left image: Self-directed learning. Right image: Healing plants.

Table 2. Learning design for documenting indigenous knowledge.

Title	Documenting my parents' and grandparents' knowledge about healing plants
Purpose	Recovering indigenous knowledge and valuing ancestral Aymara wisdom.
Learning outcomes	LO1: Investigate by asking community elders about the healing properties of local plants. LO2: Summarize findings in short descriptions using *Write*. LO3: Create digital images, photos, or sketches of the plants. LO4: Demonstrate oral communication skills in a presentation.
Learning activities or procedure	• Learners are introduced to the activity with a brief discussion related to diseases and how to heal them. • They reply, in the discussion, to the following questions: - *What kinds of diseases are there in the indigenous community?* - *How do community elders heal diseases?* - *What plants do they use for healing?* - *What are the healing properties of the local plants?* • Indigenous children are encouraged to ask their parents or elders questions about the healing properties of local plants. • Children are asked to write short digital descriptions about indigenous healing plants and their healing properties. • Children capture images, take photos, or draw sketches of the plants. • Learners organize the descriptions and photos to give oral presentations of the findings to their peers.
Materials or resources	• Local plants with healing properties. • XO laptop. • Open-source software included in the XO laptop: *Write, Record, Draw.* • Offline Wikipedia, to be used for searching technical nomenclature.
Settings	• Informal learning environments: Learners' homes, community, and natural settings (e.g., mountains).

Case example B: Documenting indigenous knowledge about healing plants. In this second learning design, the researcher asked the children to document the Aymara knowledge about local healing plants (this indigenous knowledge is a heritage from their ancestors). The participants were four girls: two seven-year-old second-graders and two 11-year-old sixth-graders. They collected data from their parents and grandparents at home and created digital texts using the software *Write*, which is included in the XO laptops. They also documented their work, including photographs of the local healing plants (see the right image in Fig. 1). They compiled data of approximately a dozen local healing plants. For example, they reported that the leaves of the *nabo mostaza* help to reduce swelling, *turu-turu* can be used for healing liver diseases, *llanten* can be used for healing wounds and other injuries, and *kantuta* can be used for headache relief.

Up to now, there is no complete systematized documentation of the Aymara knowledge about healing plants. Some partial studies have been carried out at universities [44], but this is not enough considering that a significant amount of indigenous knowledge could be lost to the next generations. Table 2 shows the learning design of this second case example.

Table 3. Learning design of the robotics project.

Title	Creating a robotics project to protect crops from frost
Purpose	Design a project to solve a community problem.
Learning outcomes	LO1: Identify the indigenous community's problems and propose a solution to a community problem. LO2: Create an artifact using a WeDo robotics kit to solve the chosen problem. LO3: Show advanced communication skills in arguing and defending the solution before a jury of expert adults.
Learning activities or procedure	• Learners are introduced to the activity through questions: - *What are the main problems in our indigenous community?* - *How could we help to solve those problems?* - *What alternatives could we provide to improve the situation?* • After being grouped by friendship, the indigenous children brainstorm ideas on the main issues and problems faced by their community. • They then write down two to four main problems and try to provide solutions through brainstorming. • Finally, they select one key problem and start developing a project for solving the issue, including ICT tools as part of the solution. • Through trial and error, they improve their solution. • They present their solution before a diverse audience (i.e., to their peers, to the whole school and in a science fair).
Materials or resources	• WeDo robotics kit pieces. • XO laptop for writing the code used to control robotic sensors. • Additional disposable materials to enhance the project idea. • Offline Wikipedia, to be used for searching technical explanations.
Settings	• Informal learning environments: Learners' homes, the schoolyard (for presentations), and another city (for the science fair).

Case example C: A robotics project to demonstrate how to protect crops from frost. This learning design revolved around the preparation of a project to be entered into a regional science fair. The volunteer participants selected a project by themselves. There was only one simple requirement: select a problem that the community is facing and propose a creative solution to that problem. Two volunteer boys – a 10-year-old fourth-grader and an 11-year-old fifth-grader – came up with the problem of winter frost, which damages crops throughout the community every year. They decided to design a project using the WeDo robotics kit to provide a solution. Previously, they had been given a basic introduction to how to control robotic sensors, and then later they designed and built an artifact to explain how to protect the crops. Their artifact consisted of pieces of brick arranged in the shape of a fan that rotates (see Figure 2), thus simulating the breeze or wind moving the air around to prevent the frost from settling in one spot and damaging the crops. In the final project, the fan propellers were replaced with paperboard so that the fan could rotate faster.

While building their projects, the children received feedback from the researcher so that they could improve the artifact's functions. After completing their project, they presented it to the other children and teachers at their school. They then traveled to another town to participate in a science fair, where they presented their project before a jury of government officials and science teachers. Although they did not win the competition, it was a great experience for them to leave their small rural community and exhibit their work in front of adults and experts from the city. This was the first time since this rural school's establishment in the 1980s that any of its students have participated in a science fair. Table 3 shows the detailed learning design of the robotics project.

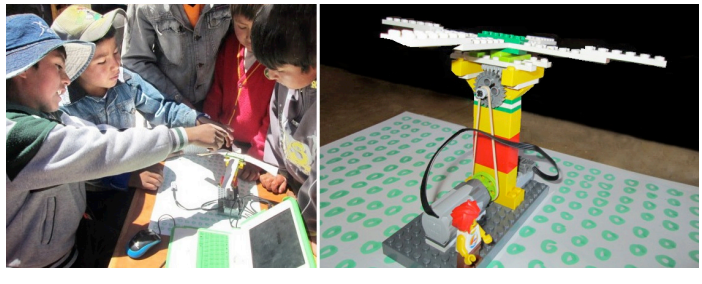

Fig. 2. Left image: Project to protect crops from frost. Right image: Robotic fan

5 Discussion

In general, people have an artifact-oriented view of technology. This is the main role attributed to technology: it is a tool or artifact. People often forget the other critical roles of technology that also impact our societies, especially those of indigenous people. This situation brings many challenges as well as many opportunities.

The learning designs presented in the previous section portray different pedagogical approaches, different technologies, and different settings. They will be discussed while relating the case examples to the roles played by technology. As de

Vries [7] mentions, there are four general roles that technology plays: a tool, a form of knowledge, a process, and a set of values. These roles, as they are carried out in learning designs to support indigenous children's learning, are highlighted below.

5.1 Technology as an artifact or tool

The learning design of the robotics project for protecting crops from frost demonstrates that artifacts are crucial to ICT in education. Not only can indigenous learners use artifacts for learning, but an artifact can also be the outcome of a project.

The pedagogical approach employed in this case example (i.e., the project-based learning approach) is well-known among science educators and employs projects in learning activities [45] [46]. This learning design was flexible and gave students adequate time to perform trial-and-error activities until the learners felt their robotics project was complete. They received feedback from the researcher, who acted as a facilitator. The learning design also required the students to present their project in another city located far away from their indigenous community. Therefore, participants' communication skills were gradually improved through presentations before their peers, before the whole school, and finally, before the science fair jury and assistants.

The introduction of robotics to indigenous children was welcomed as a new way of expression. Thus, the children used small pieces to build artifacts while enhancing their creativity and imagination through effective hand-eye coordination. Initially, they were surprised to see that the robotic sensors let them interact with the artifacts they had created. As a result, some of them were motivated to very quickly learn how to code it. In addition, the children combined their creations with the use of other materials, such as a 'ghost' made of paper to represent the fearsome frost and enhance the demonstration of the robotics project.

The settings for this learning design varied from (a) performing trial-and-error activities at home as well as receiving some feedback during after-school meetings, (b) presenting before peers and teachers in the schoolyard and (c) the science fair carried out in another city that required presenting before a jury of experts. Offering multiple settings and informal learning environments [20] [47] helps to construct knowledge more diversely and holistically to fit the way indigenous people learn, and this way of learning is supported by mobile technologies [48] [49].

When viewed from a cultural perspective, children were encouraged to use technology to solve the problems facing their Aymara community, showing that combining technology with indigenous knowledge could become a powerful synergy. For all the indigenous children in Huilasipe, this was the first time they had used LEGO® building blocks and robotics kits. Most of the volunteer children initially created simple models and later built complex moving models.

5.2 Technology as knowledge

The learning design of documenting parents' and community elders' knowledge helped to recover indigenous knowledge about Andean plants' healing properties. This case example shows the role of technology as a type of knowledge or expertise

in the form of oral traditions. The shared indigenous expertise was collected and kept in a digital form (e.g., digital text, digital pictures).

The pedagogical approach employed included the participation of parents and community elders as a source of knowledge and expertise [50] [51] [52]. This approach allows the inclusion and validation of indigenous knowledge into mainstream formal education. At the same time, it protects the cultural heritage and shows respect for indigenous worldviews. It should be emphasized that indigenous knowledge is holistic and not discipline-based [26] [53]. Nevertheless, a schoolteacher who designs this kind of learning activity could include indigenous knowledge in a formal subject. For example, Andean plants' healing properties could be included in the subject of science and technology, which is part of the official Peruvian curriculum for primary education [54].

This learning design (a) expands the knowledge of the world by including the Aymara ancient knowledge about healing plants, (b) recues the indigenous heritage from being lost forever, and (c) gives alternatives to healing world diseases. More research is needed to learn from indigenous people about diverse topics such as natural environmental conservation, ancient agricultural methods, and indigenous technologies.

The multiple settings for this learning design were children's homes, outdoor settings (i.e., natural environments for gathering pictures of local plants), and the community itself for collecting data from indigenous elders. There are several benefits to using multiple informal settings, including opportunities to learn with and from others, and to foster a love of lifelong learning [47].

Culturally speaking, indigenous knowledge has not been valued or considered 'appropriate' for inclusion within the educational curriculum. Nevertheless, the Aymara people were very eager to share their knowledge regarding local healing plants. Collecting the data required children to talk with elders and to value their own heritage. Moreover, gathering information using technology was straightforward.

5.3 Technology as an activity or process

The role of technology as a process of change and transformation was presented in the learning design that includes self-directed and out-of-school learning. The learning activity was an open-ended exploration carried out by a ten-year-old indigenous boy who pursued his own interests. There has been a lot of research on this kind of self-directed learning [25] [55] [56], which is facilitated by the dynamic use of technology.

The pedagogical approach employed in this learning design supported personalized and self-motivated learning. In other words, it was initiated by the indigenous learner himself. Self-directed learning is also a characteristic of lifelong informal learners. Indigenous people are informal learners who 'learn any time any place' in their daily lives [26]. This flexible approach has garnered much support because it provides an alternative to mainstream education, which is very structured [55] [57] [58]. It creates safe spaces for learning that implement essential characteristics, such as freedom to explore, activities led by learners' own interests, learners engaged in groups of mixed age, free choice to participate in activities, and

the use of technology. These characteristics enrich and support the learning of indigenous children.

This kind of self-motivated learning emerged from the use of the technology (i.e., XO laptops) and became an interactive and transformative process. It must be highlighted that in this case example, the use of technology allowed the boy to transition from being dependent to being an autonomous learner. Several aspects of the learning process allowed this transition to occur: (a) open-ended activities, (b) interest-based problem solving, (c) creativity, and (d) informal environments [59]. The setting for this learning design was the learner's home and the outdoors as the boy spent his spare time tinkering with his XO laptop. This informal learning environment provides a safe space for exploratory interactive experiences and nurturing curiosity, discovery, and self-directed learning.

Regarding the cultural context, this was the first time that Peruvian indigenous children could take laptops home with them, and the laptops served as a novelty for the Aymara families in Huilasipe. Thus, having a personal XO laptop at home encouraged some of the children to tinker with and explore the machine's functions. In a rural context where families have no access to television or the internet, there is much space for children's curiosity to prompt them to discover hidden functions of the technology on their own.

5.4 Technology as a set of values

This fourth role of technology is embedded in all the other three learning designs that have been presented previously. Indigenous values, worldviews, and traditions are at the core of all the learning designs [60], as their wisdom and ways of life are integrated into the activities carried out by children. The indigenous approach of learning by doing [61], the recovery of indigenous knowledge [51] [52], and the integration of technology to help find a solution to a problem facing the community [45] [46] enriched the pedagogical approaches and practices through respecting and including the Aymara perspective and heritage [62].

The technology, conceptualized as a set of values, is relevant for dealing with socio-cultural aspects. For example, in the case of Aymara learners, the use of ICT in creative ways while respecting the indigenous culture and customs, encouraged indigenous children to preserve their authentic Aymara identity.

Moreover, any technology can become a carrier of the values and worldviews of those who create it [63]. Therefore, it is important to support the inclusion of indigenous knowledge in the development of technology. In other words, indigenous people's access to technology should not be limited to the mere use of technological devices but should also include their transition from being users to being creators and active participants in preserving their cultural heritage in a digital world.

6 Conclusions

Three illustrative case examples of the use of digital technologies in an Aymara school in Peru were discussed. The cases were analyzed by employing Mitcham's [8] structure to conceptualize technology as an artifact, as knowledge, as an activity, and

as a set of values. This study does not make generalizations, but it does highlight the following significant points about developing learning designs for indigenous children using ICT:

- It is important to understand the socio-cultural context and complexities that exist in indigenous communities, as they are vital to the proper design of meaningful learning activities.
- To include community elders in learning activities, while children could be intermediaries for preserving their indigenous heritage.
- To provide indigenous children with opportunities to design models and create solutions that combine their Aymara knowledge with the use of ICT. Thus, they could be able to share their solutions with others outside their own community.

The present study contributes to filling the gap mentioned in the literature [42] [43] regarding the need to present practices on how to embed ICT into learning designs for indigenous children while considering their cultural context. The learning designs presented here were based on indigenous learners' interests and motivations [64], having groups of mixed ages [65], and employing a flexible pedagogical approach [55] [58] in informal learning environments [46] [42] [66].

Possible constraints to scaling up, in many rural schools, the learning approaches discussed in this study include: time limitations, lack of ICT resources and lack of teachers' training. Moreover, the national standardized assessment evaluates students based on the national curriculum. However, these learning approaches could be implemented through rural school networks [67] that comprise from 15 to 20 schools. Also, training volunteer teachers who, working in teams, could support each other and share their learning designs. Young teachers are especially eager to use ICT in learning activities.

In sum, we shape technology as much as technology shapes us. Therefore, rather than considering technology 'against' indigenous cultures, the understanding of the key roles played by technology could help integrate ICT to support indigenous communities, to disseminate their knowledge and to preserve their heritages [68] [69] [70].

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