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RESEARCH ARTICLE

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Bringing cultural inclusion to the classroom through intercultural teaching practices for science education (ITPSE) and guiding tools

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Abstract

Intercultural teaching practices for science education (ITPSE) are suitable to support science teachers in bringing cultural inclusion into their classrooms. The epistemological bridge is the base of the ITPSE design since this approach describes culturally inclusive teaching of science. There is an ITPSE of planning and one of enactment. With those ITPSE, teachers engage students in explaining a phenomenon from science's epistemology and nonhegemonic cultures' epistemologies. Design-based research is the methodology to produce the ITPSE through three design–test–design cycles. This paper reports on the third cycle to identify evidence to redesign the ITPSE. As a result, the teacher enacted through the ITPSE a version of the epistemological bridge very close to the framework. In addition, her reflection and feedback pointed to the guiding tools refinement.

KEYWORDS

culture, epistemology, inclusion, interculturality, teacher education

1 | INTRODUCTION

Intercultural teaching practices for science education (ITPSE) are an alternative to support science teachers in bringing cultural inclusion to the classrooms. Some authors describe cultural inclusion and exclusion in science classrooms as power relationships between epistemologies (Ludwig & El-Hani, 2020; Mpofu et al., 2014). In general,

science curriculums promote the epistemology of science (knowledge, values, and ways of knowing) and exclude epistemologies of nonhegemonic communities (Castaño Cuellar & Bravo Osorio, 2022; Ocoró, 2021). In the case of Colombia, local, traditional or nonhegemonic epistemologies belong to indigenous, Afro-descendant, mestizo, farmers, and other communities. Some education policies suggest taking into account the epistemologies of nonhegemonic communities in the classroom, but there is a fail in their restricted view of inclusion (Baronnet & Morales-González, 2018; Rodriguez, 2015; Rodriguez & Morrison, 2019), comprehension by teachers and enactment in the classroom (Guido & Bonilla, 2010; Tarozzi, 2012). Thus, the questions arise—How does the ITPSE guide teachers to a culturally inclusive practice? How does the evidence guide the ITPSE redesign?

The ITPSE are the product of a design-based research (DBR) project, and this report displays the third cycle. Thus, the path for the design of the ITPSE began with identifying the epistemological bridge as the most suitable approach to achieving epistemological inclusion in science classes (Tovar-Gálvez & Acher, 2019). The epistemological bridge describes the power relationships between cultures and guides teachers towards a culturally inclusive practice and the students' learning output from such inclusion. Then, the first cycle tested the ITPSE used by a teacher in Colombia. The evidence demonstrated the need for an auxiliary theory, in addition to the epistemological bridge, to better guide teachers in specifying the student learning product (Tovar-Gálvez & Acher, 2021). The second cycle tested the new ITPSE used by another teacher in Colombia. Again, the evidence demonstrated the need for auxiliary theories to better guide teachers in connecting the contents to the students' learning output (Tovar-Gálvez, 2023). The current study provides a teacher with the third design and collects data to refine the ITPSE possibly.

1.1 | Relevance of ITPSE design

The ITPSE are an attempt to overcome the exclusion of the epistemologies belonging to cultures different to the Western hegemonic. With the ITPSE, teachers might contribute to inclusive social, educational and learning processes. At a social level, teachers might contribute to social justice, peaceful coexistence and participation (Council of Europe, 2008; OECD, 2010; UNESCO, 2006, 2008). The justice, coexistence and participation of the nonhegemonic communities could emerge from the science teachers' practice. Thus, when teachers recognize the existence of other viewpoints different to the ones stated in the official curriculum, they might lead students to recognize cultural diversity. Moreover, when teachers validate those nonhegemonic epistemologies as a reference to explain and intervene in reality, they offer students the possibility to understand the world from different perspectives. In addition, when teachers use or incorporate nonhegemonic epistemologies as content for the science lessons, the students can participate in the different epistemologies—the hegemonic and the nonhegemonic.

Teachers at the planning and teaching level count on practical support to identify, organize and articulate content (epistemologies) from different cultures to guide students' learning output. On the one hand, the official curriculum provides teachers with a version of the knowledge, values and ways of knowing belonging to science. On the other hand, the ITPSE guide teachers to select knowledge, values and ways of knowing from the nonhegemonic cultures as content to organize and connect with the students' learning output. Likewise, the ITPSE offer teachers some tasks and tools to guarantee a reciprocal relationship between the epistemologies—all the epistemologies are relevant and valid as content to conduct the students' learning output.

Regarding students' science learning, the ITPSE guide teachers to make it easier for students to understand the nature of science through inquiry (Akerson & Hanuscin, 2007; Schwartz & Lederman, 2002). As the ITPSE design defines explanations of situations as the students' learning output, the students are engaged in scientific inquiry. In this process, the students address scientific ideas, collect and validate data, and interpret data from the ideas to build explanations (McNeill & Krajcik, 2012). Moreover, when students address science compared to other epistemologies, they access two opportunities—to understand better the structure and domain of science and

transiting between epistemologies (Meyer & Crawford, 2011). This transit means participating in the knowledge, values and ways of knowing belonging to every epistemology.

2 | INTERCULTURAL TEACHING PRACTICES FOR SCIENCE EDUCATION

The ITPSE are an embodiment of the epistemological bridge (Tovar-Gálvez, 2021) that describes an epistemologically inclusive didactics of science (planning, learning, teaching, and assessment). This embodiment describes the teachers' expected performance through tasks. In addition, teachers count on guidance tools to develop the tasks. The design consists of an ITPSE of planning and one of enactment, which comprises specific tasks. However, the ITPSE are flexible because teachers may choose or propose the activities to carry out the tasks. This flexibility is a possibility to make the ITPSE transferable and adaptable to other educational contexts.

2.1 | Vision of epistemology and curricular decisions to design the ITPSE

As part of the culture (Collste, 2019), epistemology is a human production and part of communities' references to understand and act in reality. Consequently, accepting cultural diversity leads to accepting epistemological diversity (Medin & Bang, 2013). Moreover, if accepting culture as a more or less dynamic phenomenon, then epistemologies are dynamic. For this research, epistemology is the system of knowledge, values and norms, practices or procedures, and conventions or languages communities use to interpret, explain, give meaning, and act or intervene in reality.

As a branch of philosophy, the epistemology of science addresses the nature of science and offers epistemologies (epistemological models or versions of science) (Siegel, 2014). Those epistemologies are the base for researchers to study students' and teachers' beliefs and understandings of science. Moreover, teachers, researchers, educators, and policymakers also use different epistemological models to propose the school science or what the curriculum will teach about science and how. Thus, versions of science as inquiry or research support project-based or inquiry-based teaching of science. Social and complex ideas of science lead teaching models such as Science-Technology-Society, Science-Technology-Society-Environment, or Socio-Scientific-Issues. Interdisciplinary ideas of science are the base of teaching models such as Science- Technology-Engineering-Mathematics (+). Furthermore, ideas of science as a system of practices that do not follow a unique sequence support teaching scientific practices. However, epistemology visions are also crucial to structuring learning progressions of science (Smith & Wiser, 2015).

On the other hand, epistemologies of nonhegemonic and nonrepresented cultures in the curriculum offer inputs for cultural inclusion in the science class. Researchers understand indigenous knowledge (IK) or traditional environmental knowledge as (a) science (Brayboy & Castagno, 2008), a kind of science (Snively & Corsiglia, 2001), or an indigenous version of science (Rahmawati & Ridwan, 2017), (b) as a complement of science (Erinosho, 2013; Saito, 2014), and (c) as an autonomous system with an inner value and validity (El-Hani & Souza de Ferreira Bandeira, 2008).

As an example of the last focus, Castaño Cuellar and Bravo Osorio (2022) characterized Colombian indigenous preservice teachers' epistemological and ontological views in their bachelor's final work (thesis). These indigenous belong to the Muruy, Bora, Muinane, and Okaina ethnicities and converge on the Universidad Pedagógica Nacional campus of the municipality of La Chorrera in the Amazonas, Colombia, to become biology teachers. The traditional IK, identified in the thesis documents studied, encompasses at least: (a) Territory, which includes nonhuman living and spiritual beings, constituting then the life of indigenous people. Thus, taking care of other beings guarantees human life. (b) Rituality, as the relationship practices with other beings in the territory. (c) Spirituality is the recognition of the common origin of everything in nature, including human life. New generations receive this

understanding of life through the Word of Life. When humans do not obtain the Word of Life, there is disequilibrium, and life is in danger. Therefore, the researchers identify the ontological unity of human being-nature-spirituality that must be harmonious to ensure its existence.

Another example of an autonomous nonhegemonic knowledge system belongs to the Afro-Colombian community in Guapi, Colombia. López et al. (2011) describe healthcare practices carried out by Remedieros ("the one who provides remedy"—traditional nonprofessional healers). For the authors, visions of health, disease, care and cure are a product of the communities' cultures. The researchers found that Remedieros heal diseases, wounds and infections. They obtain their knowledge through oral tradition since they are children. The community recognizes Remedieros as a health authority. Remedieros' traditional healthcare practices are (a) plants, (b) foods, (c) sobijos (therapeutic massages), (d) bebedizos (medicinal mixture based on the traditional alcoholic drink "Viche"), and (e) baños (baths with special healing plants). The practices have different purposes in the healing process: (a) maintenance of health, (b) protection to avoid situations that promote diseases, and (c) recovery. Remedieros such as Sabios (Wise Pople, Sages, or Elders) also can know and use other health specialities and enact magic rituals.

For the ITPSE design, a general model to bring scientific and nonhegemonic epistemologies to the classroom is an option to carry out cultural inclusion, but it is also a risk. This research defined a general model, understanding epistemologies as the system of ideas and practices belonging to a culturally differentiated community. The specific definition of "ideas" and "practices" is part of the ITPSE design as prompts (see pp. 1107–1108). Thus, teachers count on two general categories as an option to organize the epistemologies as content. This curricular decision has the limitation of being a school version of each epistemology and possibly representing deformations, simplifications or essentialism (Chevallard & Bosch, 2014). However, as the epistemological bridge describes below, the model to represent the relationship between epistemologies is based on epistemological pluralism and interculturality.

2.2 | The epistemological bridge as a frame to design the ITPSE

Bridges aim to communicate distant places through a shared space. Cultures are "remote places," and communication is a way to ensure comprehension and pacific connivance. Therefore, the epistemological bridge is the didactic process (planning, learning, teaching, and assessment) by recognizing, validating, and using/participating in the epistemology of science and epistemologies of nonhegemonic cultures (Tovar-Gálvez, 2021). Thus, during the planning, teachers would recognize the ends of the bridge (epistemologies) as valid content for teaching and learning. Moreover, teachers would identify common paths (aims, processes, values, and others) to communicate the endpoints. Then, teachers would engage students in participating in every epistemology domain (ideas, values, and practices). This participation consists of learning the content or domain of an epistemology (endpoint of the bridge). For this, students would cross the own epistemological border, transiting through the commonalities (pathway of the bridge), and entering the new epistemological domain (endpoint of the bridge). The transit is for everybody in every direction and at any moment. See Figure 1.

The epistemological bridge, as described above, proposes that students learn the epistemology of science while retaining the epistemology of their communities. In addition, the epistemological bridge encourages individuals in or closer to the Western culture to learn about the nondominant epistemologies while retaining their own epistemology. Crossing epistemological borders and transiting between epistemological domains does not mean leaving one's beliefs, identity, and epistemological commitments. However, individuals and communities decide where they desire to remain on the bridge. Thus, some communities could opt to go back and forth between epistemologies and use them according to the cultural contexts. For example, some individuals could desire to enter and stay in the scientific epistemological domain. Others could want to enter and stay in an Indigenous epistemological domain. Moreover, others could elect to stay in the common pathway and build a new epistemological model or cultural identity.

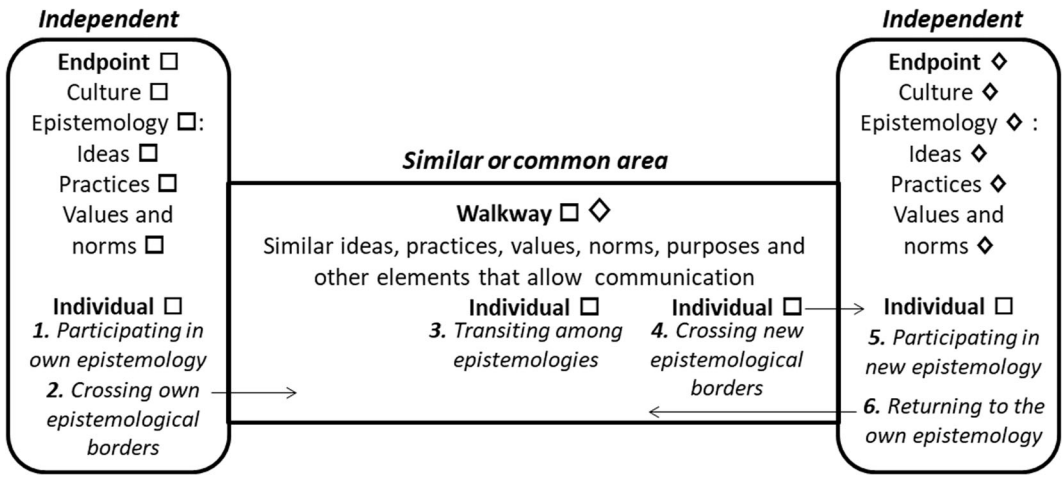

FIGURE 1 Metaphor of the epistemological bridge between different cultures. *Source*: Own elaboration.

There are different theoretical positions regarding individuals who transit between epistemologies (cultures) supporting the mentioned possibilities. First, for authors like Kuran and Sandholm (2008), individuals can move between cultures. Specifically, Bang and Medin (2010) argue that students can navigate between epistemologies and adopt them simultaneously. From another perspective, subjects count on the possibility of adaptation to different cultural contexts (Berray, 2019; Seiler, 2013). However, other positions argue that individuals may hybridize cultures (Grimberg & Gummer, 2013) or permanently build cultural identities (Anzaldúa, 2016).

On the other hand, it is convenient to go from the metaphor to practical principles to employ the epistemological bridge to design teaching practices, units, sequences or experiences, courses, programs, and materials. The principles of epistemological independence and epistemological similarity make the epistemological bridge operational. The learning output chosen for the ITPSE design is the explanation. The explanation is the possible meaning that students might assign to a phenomenon from different viewpoints—epistemology of science and epistemologies from nonhegemonic cultures. See the connection among the mentioned elements in Figure 2.

2.2.1 | Principle of epistemological independence

This principle consists of "recognizing that there are diverse epistemologies with their nature, structure, dynamics and intrinsic value." This principle comes from epistemological pluralism, which proposes that cultural diversity is also a diversity of epistemologies, and those epistemologies are valid as worldviews (Lowan, 2012; Mpofu et al., 2014; Sedano, 2013; Valladares, 2011). Furthermore, the epistemologies are independent and have a specific domain. Therefore, including nonhegemonic epistemologies in the curriculum is not a detriment or distortion of science (Cobern & Loving, 2001; El-Hani & Mortimer, 2007).

Teachers would achieve epistemological independence when they recognize every independent epistemological domain, validate them as a viewpoint to explain phenomena and use them as content. Moreover, teachers would achieve epistemological independence when they engage students to participate in each epistemology. This participation is without prioritizing one epistemology over the other, without mixing them, without explaining one from the other, or without validating or invalidating the one from the other. In this way, students would propose explanations of the same phenomenon from different epistemologies.

The next hypothetic case illustrates the principle. Context: San Basilio de Palenque is a village founded around 1599 by fugitive Africans who had come to Colombia enslaved by the Spanish. Its freedom was decreed in 1691 by

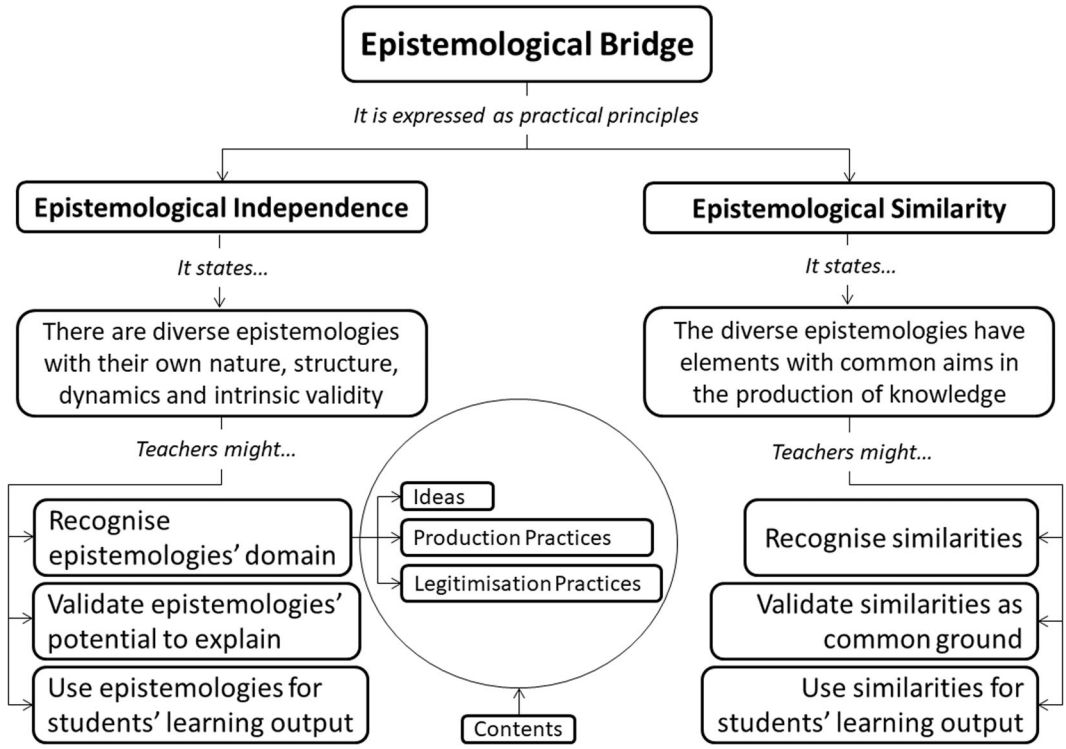

FIGURE 2 Epistemological bridge and practical principles. *Source*: Taken from Tovar-Gálvez (2021).

the Spanish crown. The population has preserved the language, among other elements of African culture. UNESCO proclaimed Palenque a Masterpiece of the Oral and Intangible Heritage of Humanity in 2005. Practice: the teacher presents to the students the situation "the children of the school are diverse—why is their hair different?" To guide the students to propose explanations for this phenomenon, the teacher addresses from an Afro-Colombian viewpoint: (a) the idea of "The hairstyles of San Basilio de Palenque as an African code of communication and resistance," (b) the practice of "making traditional African braids," and (c) the practice "teaching of the language of hairstyles to other students." Moreover, from chemistry: (a) the idea of "molecular structure and chemical properties," (b) the practice of "synthesis of organic and inorganic salts to study color," and (c) the practice of "communication of findings through scientific papers." The teacher leads students to explain hair diversity as a phenomenon caused by (a) the community history and traditions and (b) the chemical structure of molecules. They would not mix the epistemologies and explanations or establish a hierarchy among them.

2.2.2 | Principle of epistemological similarity

This principle consists of "recognizing that the diverse epistemologies have elements with a common aim in the production of knowledge." This principle comes from interculturality, which proposes that the processes of exchanging, learning and negotiating between cultures are possible because individuals might cross cultural borders (Aikenhead, 1996; Aikenhead & Michell, 2011). After crossing, individuals transit between cultures (epistemologies) using common elements (Becker & Ghimire, 2003; O'Flaherty et al., 2008) that constitute an intermediate zone or intersection between cultures (Mpofu et al., 2014; Teo, 2013). The epistemologies have similarities that motivate

the interchange but respect the independence. When students transition between epistemologies to participate in the different domains, they can produce outputs enriched by diverse cultures (Castaño, 2009; Valladares, 2011).

Teachers would achieve epistemological similarity when they engage students in identifying elements of each epistemology that are similar to each other and that motivate the borders crossing, transit, and participation in every epistemology. These elements might be practices, activities, processes, artefacts, devices, norms, actions, goals, and others that are common among epistemologies and resemble each other in their purpose and use by the communities.

Continuing with the hypothetic example, the teacher engages the students in identifying similarities among the cultures used to explain the hair phenomenon. One of the similarities is that "Afro-Colombian and scientist communities use specific and specialized language." Communities use languages to communicate their knowledge, practices, products, values, rules, and more. So, specific language is a common characteristic among the communities. When students use the languages, they do not mix the languages of the communities, neither try to identify one of them as more important than the other nor try to make "corrections" or "precision" from one language over the other. Moreover, when students are aware of the independence of the different languages, they have the opportunity to transit voluntarily between them.

2.3 | Explanations as a learning output from the epistemological bridge

The explanation is a meaning that students might assign to a phenomenon from different viewpoints. Thus, from the epistemological bridge, students produce explanations of a phenomenon from the epistemology of science and epistemologies from nonhegemonic cultures. Likewise, the explanation, as the learning output, is the horizon to follow during the planning and teaching. Thereby, teachers propose to students a situation to explain, for which they participate and use both epistemologies.

The phenomenon that teachers present to students should be an everyday situation that describes experiences, events, anecdotes or actions in the daily life of students (Wartha et al., 2013). Moreover, teachers motivate the construction of explanations by formulating one or more questions that guide students' proposal construction (Eder & Adúriz-Bravo, 2008). Teachers also count on a structure to guide students in the explanation construction. Thus, McNeill and Krajcik (2012) define a scientific explanation as a statement or conclusion that students propose on a studied phenomenon, supported by evidence and reasoning (interpretation of data from scientific ideas). The explanations from other epistemologies might follow this same structure—statement, evidence, and reasoning.

2.4 | ITPSE of planning: Building the epistemological bridge

The teachers' expected performance is to build the epistemological bridge process. In this process, teachers should make decisions on the contents, connections between them, and connections to the learning output. For this ITPSE, the students' learning output is the independent explanations of the same phenomenon from the epistemology of science and epistemologies of nonhegemonic cultures (Indigenous, Afro-communities, farmers, immigrants, and others). The contents are scientific ideas and practices and nonhegemonic cultures' ideas and practices. Some values, aims, practices, devices or artefacts are in common between the contents or have a similar purpose. Students' participation in the different practices aims to provide them with evidence to explain the situation from each epistemology. Teachers count on three tasks to achieve this performance:

Planning task 1: Propose a daily situation for engaging students in its explanation using diverse epistemologies. The students' learning aim is to participate in both epistemologies. The students' learning output is the explanation of the same situation from each epistemology.

Prompt: Epistemology is a system of knowledge or ideas, values and norms, experiences or practices, materials, and devices or instruments that communities use to produce knowledge, goods and services. Science is an epistemology emergent from western culture. Cultures different to the western or westernised have other epistemologies.

Planning task 2: Organize the knowledge and experiences of each culture, as independent content, according to the categories—ideas, production practices, and legitimization practices, to engage students in proposing explanations of the phenomenon described in the situation.

Prompt: An idea is a connection between concepts, values, and practices which has the power to describe or give an account of phenomena. Production practices are all the experiences that communities carry out based on knowledge to originate information, goods, products, services, or new knowledge. For instance, in an indigenous realm, sacred rituals or the elaborations of products (clothes, medicine, ceramic, and others) would be production practices. In science, laboratory procedures are some production practices. Legitimization practices are all the experiences that communities carry out based on rules to support, regulate, normalize, recognize, and disseminate their knowledge and products. Those norms demarcate the domain of each epistemology. For example, in an indigenous realm, communities legitimize (incorporate) knowledge when young people listen to the wisdom of an Elder. In science, communities legitimize (validate) knowledge using standardized protocols to regulate procedures.

Planning task 3: Identify similarities between scientific practices and other cultures' practices to engage students in crossing epistemological borders, transiting between epistemologies, and participating in each domain to build explanations.

Prompt: The different communities have commonalities in the production of knowledge processes. Some similar or common elements are observation practices, communication practices, regulation norms, values, goals and desires, specific languages, experts, production practices, and legitimization practices.

2.5 | ITPSE of enactment: Teaching to produce explanations from the epistemological bridge

The teachers' expected performance is to teach students to propose explanations of phenomena from the epistemological bridge. In this process, teachers should engage students in the participation of each epistemology to obtain elements to construct the explanations. For this ITPSE, teachers guide students to carry out both epistemologies' production and legitimization practices without explaining, justifying, clarifying or invalidating one epistemology from the other. Moreover, teachers guide students in identifying practices, values or other elements from each epistemology, which resemble each other, as common ground among cultures. Finally, teachers guide students in producing an independent explanation of the situation from each epistemology. Teachers count on three tasks to achieve this performance:

Enactment task 1: Engage students in production practices, scientific and from other cultures, to obtain evidence on the phenomenon to be explained.

Enactment task 2: Engage students in legitimization practices of scientific knowledge by internal and social validation and legitimization practices of other cultures' knowledge by incorporation into the community.

Enactment task 3: Engage students in the production of explanations about the same phenomenon and from each culture, making use of the information obtained with the development of the practices of each community and the respective ideas.

Prompt: Both explanations should contain a statement or conclusion, evidence, and reasoning. A statement or conclusion is an affirmation, proposition, declaration or sentence that gives an account of the studied situation. The conclusion is a construction that students produce after participating in the diverse epistemologies to study the situation. The evidence is information or data about the situation that the students have collected during the

production and legitimization practices. The reasoning is the set of data interpretations by using the corresponding idea.

3 | METHODOLOGY

This study used DBR to design the ITPSE and qualitative focus to analyze the information collected after a teacher used the ITPSE. DBR is an intermediate between research and design (Sloane, 2006) to produce practical solutions to practical educative problems (van den Akker et al., 2006) for supporting educational communities in reaching their goals (Walke, 2006). For McKenny and Reeves (2012), DBR is a series of iterative cycles. The cycles consist of design–test–design until the proposal guides communities to the expected result. In addition, for Edelson (2002, 2006), DBR produces not only educational innovations but also theoretical and methodological outcomes. In this research, (a) the educational innovation is an ITPSE of planning and other of enactment, and the guiding tools, (b) the theoretical outcome is the epistemological bridge, explanations as students' learning output and the situations to motivate students transiting between epistemologies, and (c) the methodological outcome is the description of the ITPSE design trajectory.

The design of the ITPSE to support in-service science teachers in bringing epistemological inclusion to the classroom is a series of iterative cycles. During each cycle, a teacher implements the ITPSE to provide evidence of the design's contribution to the purpose. This information is the reference to evaluate the ITPSE and consider redesigning them.

Throughout the first cycle (Tovar-Gálvez & Acher, 2021), the researcher designed the first set of ITPSE using the epistemological bridge approach (Tovar-Gálvez, 2021). A high-school chemistry teacher implemented these ITPSE. The evidence indicated the design's weakness in guiding teachers to make the students' explanations concrete. This information suggested introducing an auxiliary theory on explanations (McNeill & Krajcik, 2012) and was the base for producing a second ITPSE design. During the second cycle (Tovar-Gálvez, 2023), a different high-school chemistry teacher implemented the second set of ITPSE. Again, the evidence indicated the design's weakness in guiding teachers to connect content and learning output. This information introduced another auxiliary approach to formulating a situation for students to explain (Eder & Adúriz-Bravo, 2008; Wartha et al., 2013) and a third ITPSE design. The current study is the third cycle with a new teacher to evaluate the last ITPSE version.

3.1 | Case: The salt from chemistry and indigenous viewpoints

3.1.1 | The context

A science teacher in a public urban high school in Bogotá, Colombia, participated in the project. Colombia is a culturally and ethnically diverse nation (Constitución Política de Colombia, 1991). Approximately 4.4% of the population self-identifies as indigenous (more than 140 different communities). Around 7% have an identity as Negro(a), Mulato(a), Afrodescendant, Afro-Colombian, Raizal or Palenquero(a), and the rest of the inhabitants as Mestizo, White or no ethnic group (Departamento Administrativo Nacional de Estadística [DANE], 2018). In addition, 31.8% of the Colombian population identifies themselves as Campesino(a) (Farmers) (DANE, 2020). Bogotá, the capital city, represents this diversity and shelters hundreds of thousands of Venezuelan immigrants.

Bogotá is a culturally diverse city because the population from culturally differentiated communities live or transit there. Some communities are in Bogotá mainly because their territories are there or around; others migrated because of the country's inner conflict or the dire economic situation, others came to study or establish political and cultural organizations, and others migrated from foreign countries.

The population is from a public school in the Ciudad Bolívar borough, south of Bogotá. This borough's population lives under economic impoverishment, social problems and marginalization. Many people who migrate to Bogotá displaced from their territories due to economic, political, and violent factors see this area as the only option to find a place to live. Not all who arrive in the area have access to education and other essential conditions for life. Not everyone who comes to the borough stays permanently. Part of the participant students also lives in this dynamic.

The teacher reports that the participant students were between 11 and 12 years old, and some were from different cultural backgrounds. Many students are temporarily in school, which is a limitation for attending cultural diversity. She explains that one of the biggest concerns is the loss of their culture, which implies losing their language and customs and thinking about their future from a Westernized perspective. None of them thinks about their future to return to their territory. That is a longing of the parents and the first children who arrived in the city, who remember and long for nature. However, children born in the city do not feel homesickness or attachment to a territory other than Bogotá.

The teacher does not find tensions between students or between teachers and students because they belong to farmers, indigenous or Afro communities. There is tension with Venezuelan children, but this response is more to the information circulating about them, to xenophobia and more to aporophobia. She argues for the phenomenon of aporophobia, saying that if Venezuelans come to the city with money, people will not reject them.

3.1.2 | The teacher

The teacher is Ms Marcela Puerto, and she wanted to reveal her full name. Marcela does not identify within an ethnic, cultural or racial category. She has not questioned it because "basically I understand that I am mixed race, a mixture." On a broader scale, she identifies with being Latina. Marcela reports that she has not considered whether being Latina influences her teaching practice. However, she is clear that research and teaching in Europe and the United States differ from research and teaching in Latin America. Marcela feels that many cultural factors that come with being Latina do permeate her practice. Finally, Marcela expresses that in her practice, what influences the most is that she is a woman.

Marcela holds a bachelor's degree in biology teaching and a master's in science teaching. One of the bachelor's semesters was focused on ecological diversity and, from a humanistic point of view, sexual diversity. In a course, they covered the difference between gender, sex, and identity and a bit about how to apply it to school. Likewise, the teacher introduced something about the indigenous people, specifically the Embera community; but not applied to education. Marcela expresses that they did not address how to land multiculturalism in didactics. She also says she did not receive instruction to identify and teach neuroatypical students either. She reflects and concludes that she received at the university an education to teach healthy children from functional families and in privileged contexts. Nonetheless, "no one told us we would find children with learning disabilities, syndromes, diseases, pathologies, and children from culturally diverse classrooms."

She understands cultural diversity as the "variety of people and the natural and cultural patterns constituting them as a community." It is the first time she will develop an educational experience of this nature, but she had previously been in a presentation by the researcher in Bogotá. She has 17 years of teaching experience at the moment of the data collection.

3.1.3 | The process with the ITPSE

The goal was to gather evidence to empirically inform the design through the teacher implementation of the third version of the ITPSE.

During the first phase, the researcher interviewed the teacher about her perceptions of cultural diversity in her school and how she addresses it in her chemistry class. The researcher also presented her ITPSE proposal and the tools. The planning process took almost 2 months, during which she provided three versions of the planning tool and obtained feedback from the researcher. She counted on the planning tool, an explanations tool and examples of explanations. The planning tool is a form with a schema describing the tasks for developing the aim of the ITPSE and with prompts detailing the tasks and examples. Some questions are included in the form to promote teachers' reflection on possible learning issues and possible solutions. The explanations tool is for her to plan the expected students' learning product, and at the same time, she can provide students with the same tool for them to propose the explanations. Such a tool has a section to describe the situation to explain, a section for both conclusions (claims) on the situation, another for registering evidence obtained during both production practices and legitimization practices, and a section to point out similarities between the epistemologies. This tool also contains prompts.

During the next phase, the teacher developed lessons using the ITPSE. In 6 weeks, the teacher conducted two classroom sessions and two practical experiences with one group of students. The teacher provided recordings of the class: videos, images, graphics, and slides. There are also audio recordings of the reflection and feedback process between the teacher and the researcher. She followed her planning proposal and modified it when necessary. At the same time, the teacher used examples of explanations to guide students to specify their explanations in the corresponding tool. The contents in which the engaged teacher students are in Table 1.

3.2 | Data sources and collecting

The data emerge from (a) what the teacher says in class regarding the epistemologies, (b) what the teacher does while engaging students in ideas and practices, and (c) material designed by the teacher. The sources are the teacher, students, and the researcher. The information collecting is through the teacher's reports (class recordings, audio with descriptions and reflections on the lessons, planning tool and materials), the researcher's notes and the explanations proposed by students.

TABLE 1 Contents with which the teacher engaged the students.

Situation to explain	
In recent years, the fashion for body piercing has increased. Many piercers in various parts of the world recommend the use of sea salt (in specific proportions) during the healing process due to its healing properties. Why can sea salt help healing a piercing?	
Scientific Idea	Traditional Idea
Structure and properties of matter: substances and mixtures.	Properties of sea salt to heal wounds. Knowledge associated with Colombian farmers and indigenous communities.
Scientific production practice	Traditional production practice
Determination of the hygroscopic property of salt.	Salting of raw meat to see if salt preserves meat or not.
Scientific legitimization practice	Traditional legitimization practice
Identification of possible procedural errors when students weighed the salt.	Interview adults about how to conserve meat when there is no refrigerator. Share interviews with classmates.

Note: The teacher calls the indigenous and farmers nonhegemonic cultures as "traditional" to facilitate communication with the students. This notation is the expression for the rest of the paper.

3.3 | Data analysis

The data analysis consists of three qualitative steps—(a) grouping information under a priori categories (deductive content analysis: Cisterna, 2005; Hsieh & Shannon, 2005), (b) identifying trends in the information already grouped into the under a priori categories (inductive content analysis: Hsieh & Shannon, 2005), and (c) describing the teacher's performance while using the ITPSE. One of the categories is the "version of the epistemological bridge enacted by the teacher," which is the teacher's practical epistemology carried out in the classroom (Wickman, 2004) by using the ITPSE. The subcategories are "epistemological independence" and "epistemological similarity." The other category is "teacher's reflection on the practice and feedback on the ITPSE," which is the teacher's critical contribution to the design. This last category is a way to validate the design from the stakeholders' viewpoint and real needs (Hail et al., 2011).

3.3.1 | Deductive content analysis

The process consisted in transcribing the data collected and classifying the events, situations, moments, interactions or descriptions under two a priori categories. The subcategories guided the grouping of excerpts from the transcriptions. For example, when the teacher tells the students that the different epistemologies or knowledge systems have in common that everyone uses a specific language, she enacts epistemological similarity. Moreover, when the teacher encourages students not to mix the language from science and Indigenous systems, she enacts epistemological independence.

3.3.2 | Inductive content analysis

This part consisted of identifying patterns in the teachers' performance while using the ITPSE. Thus, the information already grouped into the a priori categories constitutes new emergent groups. For instance, under the subcategory "epistemological independence", the teacher—(a) addresses with students chemical concepts about mixtures, (b) addresses with students Indigenous concepts about the salt's value and meaning, (c) involves students in a chemical laboratory experience and a traditional meat preservation experience, (d) involves students in disseminating what they learned from chemistry and Indigenous about salt properties. In all cases, the teacher is enacting epistemological independence because she is engaging the students in the domain of every epistemology. However, there are two trends or patterns—first, in situations (a) and (b), she promotes participation in only one of the epistemologies; so, she enacts epistemological independence giving predominance to one of the epistemologies. Second, during situations (c) and (d), she promotes participation in both epistemologies; thus, she enacts epistemological independence giving the same relevance to both epistemologies.

3.3.3 | Teacher's performance while using the ITPSE

The trends identified inductively are the base to finally describe the teacher's performance using the ITPSE and her critical suggestions. This part is what appears in the results section. The description details the teacher's approximation to the epistemological bridge framework during the planning and practice. In addition, this description details the needs, difficulties and possibilities that she identified on the ITPSE and tools. Finally, the nuances show the teacher's goals and limitations reached through the ITPSE support. Therefore, the teacher's performance and critical suggestions on the design are evidence of the ITPSE's contribution to enacting the

epistemological bridge in the science classroom. This information is the reference to decide if redesigning the ITPSE and tools or not.

4 | RESULTS

4.1 | Category "version of the epistemological bridge enacted by the teacher"

The version of the epistemological bridge implemented by the teacher, using the ITPSE, is very close to the one proposed in the theoretical framework because she (a) motivated students to participate equally in both epistemologies, (b) made use of the principles of epistemological independence and epistemological similarity during the planning and enactment, (c) engaged students in the use and participation of the contents of both epistemologies (ideas, production practices, and legitimization practices), and (d) engaged students in the production of explanations.

4.1.1 | The teacher motivated the students to participate equally in both epistemologies

The teacher balanced the students' participation in both epistemologies. In this way, she guaranteed the student's participation described by the epistemological bridge. The teacher defined the traditional culture and scientific ideas upon writing the third version of the planning form and with the researcher's feedback. Although the teacher expressed difficulties understanding the objective of legitimization practices, she finally proposed legitimization and production practices for both epistemologies. During the enactment, the teacher did not prioritize with students the development of any specific idea nor preferred to engage them in the practices of only one of the epistemologies. Instead, the teacher dedicated time and designed activities to address with her students the idea and practices of each epistemology.

A relevant factor in developing the enactment tasks was the comparative charts proposed by the teacher. The ITPSE propose to teachers some tasks to achieve the aims, but they have the freedom of proposing activities, tools and material to carry out the tasks. The tool she proposed motivates students to always move forward with ideas, practices, and explanations in parallel and symmetrically among epistemologies.

Example of when the teacher motivated students to register information in parallel:

> *Teacher*: What was our question? [She points on the board the question about the situation to be explained]. *Students*: Why can sea salt be good to cicatrize? *Teacher*: From the scientific viewpoint, please look at your comparative chart from last time. Now let us look at what we can add or organize (in the chart). Hanjo, from the scientific? *Hanjo*: Because (salt) draws water (not audible). [The teacher repeats what the student said while writing on the board in the column of the scientific idea]. *Teacher*: Salt extracts water and cleans the perforation… From the traditional? *Lucía*: (salt) kills bugs. *Teacher*: But no, you should answer from what we learned today. From the traditional, does salt disinfect? *Students*: No. *Ricardo*: (Salt) prevents (meat from) rotting. *Teacher*: And why does it prevent rotting? *Emma*: Salt absorbs water and does not let bugs be generated. [The teacher wrote it on the board]. *Teacher*: Ready… it is already the third chart or the second—[see the original in Spanish below].
>
> Profesora: ¿Cuál era nuestra pregunta? [Señalando la pregunta de la situación a explicar]. Estudiantes: ¿por qué la sal de mar puede ser buena para cicatrizar? Profesora: desde lo científico, por favor miren su cuadro comparativo de la vez pasada. Ahora miremos qué podemos ir añadiendo

> u organizando [en el cuadro]. Hanjo, ¿desde lo científico? Hanjo: por lo que (la sal) extrae agua (no audible). [La profesora repite lo que dijo el estudiante, mientras lo va escribiendo en el tablero, en la columna de la idea científica]. Profesora: la sal extraer agua y limpia la perforación… ¿Desde lo tradicional? Lucía: (la sal) mata bichos. Profesora: Pero no, deberías responder con lo que aprendimos hoy. ¿Desde lo tradicional la sal desinfecta? Estudiantes: no. Ricardo: (la sal) evita que (la carne) se pudra. Profesora: Y ¿porque evita que se pudra? Emma: la sal absorben agua y no deja que se generen bichos. [La profesora lo escribió en el tablero]. Profesora: Listo… ya es el tercer cuadro o el segundo.

In the excerpt above, the teacher summarizes with students the learnings from both epistemologies and writes them in a comparative chart. The comparative charts are a form where students register advances in the situation's explanation from both epistemologies. The charts support epistemological independence because the students visualise the domain of every epistemology. Likewise, the charts support the epistemological similarity because students visualise that the epistemologies have elements in common.

4.1.2 | The teacher made use of the principles of epistemological independence and epistemological similarity during the planning and enactment

The teacher put into practice the principles of epistemological independence and epistemological similarity during planning and enactment practices. In this way, she guaranteed the recognition and validation of the diverse epistemologies as contents, as the epistemological bridge describes. In addition, however, the teacher enacted more epistemological independence than epistemological similarity.

The teacher planned and engaged students in ideas, production practices, legitimization practices, and the construction of explanations, respecting each epistemology domain. These actions are evidence of the epistemological independence enactment. However, the teacher did not enact epistemological independence in 1 event (excerpt) of 39 related to production practices. In that case, she engaged students in the nonhegemonic culture production practice but using scientific stuff. Nevertheless, the teacher reflected with students in a posterior session on the nature of each epistemology and why it was a mistake to use elements of scientific practice in a traditional practice.

On the other hand, the teacher expressed difficulty in understanding the epistemological similarity in spite of addressing it with the researcher and knowing examples. However, she planned and enacted production and legitimization practices and constructed explanations from each epistemology in parallel. The comparative charts she proposed were a tool for students to realize that both epistemologies have in common that everyone produces knowledge by experience (practice) and supports knowledge by validation or incorporation into the community (legitimization). In addition, the teacher proposed "proving" and "communicating" as practices that traditional and scientific communities have in common. She encouraged the students to prove salt's properties and respect the communication codes of every community. These events are evidence of the epistemological similarity enactment.

Example of when the teacher enacted the epistemological principles:

> *Teacher*: Regarding sea salt, let us look at how both cultures produce knowledge. *Matilde*: Both have their own processes to produce knowledge or anything they desire. [The teacher wrote it on the board]. *Teacher*: But how did we do it from chemistry? *María*: We did experiments. *Teacher*: Ah, we did experimentation; what for? *Sergio*: To prove it. *Teacher*: Experimentation was carried out to verify that it was a hygroscopic mixture [The teacher wrote it on the board]. And from the traditional, what did we do? *María*: We salted the meat, and then we saw if it was damaged. [The teacher wrote it on the board]… *Teacher*: Both (cultures) had procedures—[see the original in Spanish below].

> Profesora: ahora vamos a mirar en la sal marina cómo ambas culturas producen conocimiento. Matilde: ambos tienen sus procesos propios para producir conocimiento o lo deseado. [La profesora le escribe en el tablero]. Profesora: pero ¿cómo lo hicimos desde la química? María: se hizo la experimentación. Profesora: ah, se hizo la experimentación, ¿para qué? Sergio: para comprobarlo. Profesora: se realizó la experimentación para comprobar que si era una mezcla higroscópico [mientras va escribiendo esto mismo en el tablero]. Y desde lo tradicional, ¿qué se hizo? María: se saló la carne, para ver si se dañaba. [La profesora lo escribe en el tablero]. Ambas (culturas) tenían procedimientos.

In the excerpt, the teacher enacts epistemological independence because she carried out the production practices from every epistemology with the students. In this summarization of learnings in the comparative charts, it is evident that the teacher engaged the students in the domain of every epistemology with the same relevance. Moreover, the teacher enacts the epistemological similarity when she leads the students to evoke the learnings from every practice in parallel and concludes explicitly with "both had procedures" as a common factor between the epistemologies.

4.1.3 | The teacher engaged students in the use and participation of the contents of both epistemologies (ideas, production practices, and legitimization practices)

The teacher planned and enacted scientific and traditional ideas, production practices, legitimization practices and explanations. In this way, she guaranteed that the students participated in both epistemologies, as the epistemological bridge proposes. During the process, the teacher expressed her difficulty understanding the objective of legitimization practices. Nonetheless, she engaged students in legitimization practices of both epistemologies. The students collected evidence on the studied situation, emerging from both epistemologies' production and legitimization practices. Finally, they used such evidence to support the claim and produce reasoning.

Example of when the teacher engaged students in the contents:

> *Teacher*: I want us to be clear about one thing: we have an idea from the scientific and another from the traditional about why (salt) is good to cicatrize. But we also carried out a practice which… here [while pointing out the column of science], what was it? *Students*: Laboratory. *Teacher*: And here [while pointing out the column of the traditional], what was it? *Students*: The meat. *Teacher*: But here [pointing to the scientific column], how did we disseminate knowledge? *Students*: [inaudible]. *Teacher*: Comparing our data, showing them, saying what data we obtained over time. And here [pointing to the column of the traditional], how did we do it? *Students*: We checked whether or not the meat got rotted. *Teacher*: But how do we disseminate it? *Kevin*: Showing it to other people. *Teacher*: We presented it to other people. We presented it in the community. And how did the farmers do it? They said it to the others. They told it to the town gossip so that she could tell the whole town. The natives said it from parents to children—[see the original in Spanish below].
>
> Profesora: quiero que tengamos clara una cosa: nosotros tenemos una idea, desde los científico y de los tradicional, de por qué (la sal) es un buen cicatrizante. Pero también hicimos una práctica que… aquí [señalando maestra la columna de lo científico] ¿cuál fue? Estudiantes: laboratorio. Profesora: y aquí [señalando la columna de lo tradicional] ¿cuál fue? Estudiantes: lo de la carne. Profesora: pero aquí [señalando la columna científica] ¿cómo divulgamos el conocimiento?, Estudiantes: [inaudible]. Profesora: comparando nuestros datos, mostrando, diciendo cuáles datos me dieron al cabo del

> tiempo. Y aquí [señalando la columna de lo tradicional] ¿cómo lo hicimos? Estudiantes: mirando si la carne se podría o no se podría. Profesora: pero ¿cómo lo divulgamos? Kevin: mostrándoselo a las otras personas. Profesora: presentándoselo a las personas. Lo presentamos en comunidad. Y ¿cómo lo hacían los campesinos?, Se lo decían al otro, se lo decían a la chismosa del pueblo para que se lo contara todo el mundo. Los indígenas lo decían de padres a hijos.

The excerpt above evidenced that the teacher engaged students in participating in the contents belonging to both epistemologies. In this reflection, the teacher evokes the scientific and traditional ideas and their use in explaining the situation. Moreover, the teacher with the students recalls both epistemologies' aim of production and legitimization practices. They addressed the two kinds of content with the same relevance.

4.1.4 | The teacher engaged students in the production of explanations

The teacher planned the construction of explanations from each epistemology and engaged students in their production, using the principles from the epistemological bridge. During the planning, the teacher proposed each epistemology's content, having as the main criterion the relationship or contribution of the content to the explanation's construction. In this way, she restructured the contents toward the explanations, which is evident in the third version of the planning. Likewise, the teacher developed a version of the explanations tool to project the expected learning product. In addition, she counted on two examples of explanations provided by the researcher. During the enactment, the teacher emphasized that students identify how the addressed content contributed to constructing the explanations. For this, the teacher used comparative charts where the students registered the progress or contributions to the explanations.

The final session consisted of the collective construction of the explanations. The teacher and students took as input the comparative tables constructed and one of the examples of explanations provided by the researcher. Throughout this process, the teacher and the students enacted epistemological independence and epistemological similarity. Finally, the data revealed that the teacher needed better support to identify the purpose of the reasoning and how to build them.

Example of when the teacher engaged students in producing explanations:

> *Teacher*: Now I will detail how the work will be [while writing on the board]. We will organize a comparative chart that leads us to answer the question. What is the question? *Jorge*: Why can sea salt help to cicatrize? *Teacher*: And there are two ways to explain it. We have one from science and another from tradition. Each of them explains why water or sea salt can contribute my piercing heal. Each uses a different language—[see the original in Spanish below].

> Profesora: ahora les voy a explicar claramente cómo va a ser el trabajo [Escribiendo en el tablero]. Nosotros vamos a organizar un cuadro comparativo, que me permita responder la pregunta. ¿Cuál es la pregunta? Jorge: ¿por qué la sal marina puede ayudar a cicatrizar? Profesora: y hay dos formas de explicarlo. Tenemos uno desde la ciencia y otro desde la tradición. Cada una de ellas le da una explicación a por qué el agua o la sal marina puede contribuir a que mi piercing sane. Cada una utiliza un lenguaje diferente.

In the previous excerpt, it is evident that the teacher engaged students in constructing explanations of the initial situation from the epistemological bridge. In this event, the teacher summarizes the work done and indicates how to proceed to write the explanations. She highlights the guiding question and the two

epistemologies from which students must propose the explanations as an indicator of independence. Moreover, despite the difference, she highlights the languages as an indicator of similarity between the epistemologies.

4.2 | Category "teacher's reflection and feedback on the own practice and the ITPSE"

The reflection and feedback provided by the teacher led to identifying the design limitations. Mainly, the purpose and use of each type of content and their connection with the explanation is unclear. A part of the solution is probably the tools' refining, providing a more precise scheme and prompts that detail the aim and contents' contribution to propose the explanations.

4.2.1 | Design limitations to guide the teacher

The main limitation of the design is the contents' clarity in their aim, use and connection with the explanations. The feedback and the reflection provided by the teacher on her practice and the design revealed that the guiding tools lack detail and a structure more comprehensible for teachers. The guide should help teachers to understand the purpose of each part of the content and how they will contribute to the explanations. In this teacher's case, the main contents to clarify are the scientific idea and its connection with the situation, legitimization practices, reasoning, and how to explicit the epistemological similarity.

Example of when the teacher reflects on her practice, contributing to identifying possible changes in the support tools:

> *Teacher*: Concerning the question [to motivate students to explain the phenomenon] everything [the content] collides with the question. What students can learn is very interesting, but they definitively do not answer the question with that. And that is where I feel entirely blocked—[See the original in Spanish below].
>
> Profesora: con respecto a lo de la pregunta ya te digo [para motivar a los estudiantes a explicar la situación], todo [el contenido] choca con la pregunta. Lo que los estudiantes pueden alcanzar está muy interesante, pero definitivamente no contestan la pregunta. Y es ahí en donde yo me siento completamente bloqueada.

In the fragment above, the teacher expresses that it is difficult for her to connect the scientific idea in the official curriculum to the situation that students must explain.

4.2.2 | Opportunities to redesign or refine the support tools

The teacher explicitly stated the need for the tools to be more detailed in the contents' purpose and use. Thus, the guiding tools provided to the teacher for developing the ITPSE need a redesign. The evidence indicates the need to refine the guiding tools regarding a more precise structure and prompts regarding the contents and the epistemological independence and similarity. Comparative tables emerge from the teacher performance as a tool to address independence and similarity between epistemologies schematically. These comparative tables are a way of developing explanations step by step.

5 | DISCUSSION

5.1 | Redesign of the ITPSE and guiding tools (planning and explanations construction)

The ITPSE design is stable because teachers can follow the tasks to build the epistemological bridge while planning and enacting it with students. It can be affirmed by comparing this cycle with the previous cycles. Through the first cycle (Tovar-Gálvez & Acher, 2021), the teacher needed a structure of the explanations to follow with the students. The solution introduced the frame of explanations, a guiding tool and an enactment task. After the second cycle (Tovar-Gálvez, 2023), the teacher needed more instruction about connecting the parts of explanations and how to lead students to specify the explanations more easily. The solution introduced the frame about phenomena as everyday situations and guiding questions, refined the explanations tool and added a planning task. In this third cycle, the teacher did not need more additional tasks to develop but more clarity.

Consequently, the guiding tools require refinement to provide teachers with better and more precise indications. Sandoval's (2003) criteria to design guiding tools is a solution to refine the tools. The author proposes to improve tools using specific prompts: conceptual, epistemic, and metacognitive. The conceptual prompts are regarding the contents, the epistemic prompts about contents connections, and metacognitive prompts related to learning achievement. In the case of ITPSE supporting tools, the conceptual prompts will guide teachers regarding the contents' and explanations' aim and use. Likewise, the epistemic prompts will guide teachers regarding the relationship between contents and the situation that students must explain and the relationship between the explanation's elements (claim, evidence and reasoning). Finally, the metacognitive prompts will guide teachers in reflecting, regulating, and assessing performance achievement (Tovar-Gálvez, 2008). See the new tools as Appendices 1 and 2.

5.2 | Challenges of the designed ITPSE for future research

The ITPSE do not guide teachers to address the ideas from both epistemologies with students fully. The solution might translate into the ITPSE design in at least three aspects: (a) how to build scientific ideas, perhaps taking the advances in best practices to guide students in constructing scientific explanations (Hoffenberg & Saxton, 2015; Odora, 2014), (b) how to build nonhegemonic cultures ideas, perhaps taking the advances in how to introduce IK in the science classroom (Seehawer, 2018; Shizha, 2007), and (c) articulating both elements before under the principles of epistemological independence and epistemological similarity.

Part of the challenge is how teachers learn or approach the nonhegemonic cultures' epistemologies. Possible solutions are: (a) inviting people from the communities to schools (Aikenhead & Michell, 2011), (b) teachers immersion in the communities (Stagg et al., 2018), (c) research reports on abstractions of the communities epistemologies and or ontologies (Castaño Cuellar & Bravo Osorio, 2022; Montoya, 2020), and (d) reports on communities' direct testimonies on their epistemologies (Encarnación Galindo, 2022).

5.3 | Implications of designing the ITPSE

The ITPSE are an opportunity to enact cultural inclusion in the science classroom from the epistemological point of view. When teachers recognize the epistemologies of nonhegemonic cultures, validate their contribution to explaining the world, and use them as content, then teachers promote social justice and peaceful connivance. Considering other epistemologies in the curriculum in reciprocity with science is respecting and valuing those other cultures. Moreover, participating in the different epistemologies is a way to reach mutual comprehension and dismantle biases.

Likewise, designing practice-and-theory-based teaching supports, such as the ITPSE, enhances the teacher education field. The "teaching practices" as teacher education approach looks at designing specific teaching and learning supports that teachers probably need in practical school life. Advancements, as done by Windschitl et al. (2012), propose a set of core teaching practices for science teachers, and now the ITPSE strengthen this achievement. Furthermore, this teacher education and research approach aims to produce teaching and learning support using the current theory and, overall, the teachers' experience and needs. For this reason, the teaching practices validate teachers' feedback on the designs and teach teachers through practice, as the ITPSE process did. In addition, the ITPSE design contributes to the more general framework of teaching practices as a teacher education approach (Forzani, 2014).

To study how teachers use the ITPSE helps teacher educators, education programs designers and policymakers to diversify the science teachers' education curriculum. To know teachers' needs and troubles or adaptation of the teaching and learning supports provides valuable information on how to redesign the supports and how to teach them.

The ITPSE as a supporting tool, design process, and experience contribute to teachers' learning. For example, when science teachers recognize, validate and use epistemologies from other cultures in class, they would reflect on and criticize the imposition of mainstream culture. In such a way, teachers would have the opportunity of breaking the idea of a correct or true culture (van Melle & Ferreira, 2022). Therefore, teachers count on the ITPSE to overcome problems that Kennedy and Lopez (2022) identify in teachers' learning as—(a) they do not identify culture as a historical and sociological phenomenon, (b) they do not critic the power relationships between cultures, and) they interpret other cultures from the own culture prejudgement. Consequently, teachers might change the narratives about students belonging to nonhegemonic cultures (Karner, 2022) and start transforming the curriculum towards cultural inclusion (Tovar-Gálvez, 2022).

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CONFLICT OF INTEREST STATEMENT

The author declares no conflict of interest.

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REFERENCES

Aikenhead, G. S. (1996). Science education: Border crossing into the subculture of science. *Studies in Science Education*, *27*, 1–52. https://doi.org/10.1080/03057269608560077

Aikenhead, G. S., & Michell, H. (2011). *Bridging cultures: indigenous and scientific ways of knowing nature*. Pearson Education.

Akerson, V. L., & Hanuscin, D. L. (2007). Teaching nature of science through inquiry: Results of a 3-year professional development program. *Journal of Research in Science Teaching*, *44*(5), 653–680. https://doi.org/10.1002/tea.20159

Anzaldúa, G. (2016). *Borderlands/la frontera. The new mestiza*. Capitan Swing Libros.

Bang, M., & Medin, D. (2010). Cultural processes in science education: Supporting the navigation of multiple epistemologies. *Science Education*, *94*(6), 1008–1026. https://doi.org/10.1002/sce.20392

Baronnet, B., & Morales-González, M. (2018). Racismo y currículum de educación indígena. *Ra Ximhai*, *14*(2), 19–32. https://bit.ly/3DGiexA

Becker, C. D., & Ghimire, K. (2003). Synergy between traditional ecological knowledge and conservation science supports forest preservation in Ecuador. *Conservation Ecology*, *8*(1), art1.

Berray, M. (2019). A critical literary review of the melting pot and salad bowl assimilation and integration theories. *Journal of Ethnic and Cultural Studies*, *6*, 142–151. https://doi.org/10.29333/ejecs/217

Brayboy, B. M. J., & Castagno, A. E. (2008). How might native science inform "informal science learning"? *Cultural Studies of Science Education*, *3*(3), 731–750. https://doi.org/10.1007/s11422-008-9125-x

Castaño, N. (2009). Construcción Social de Universidad para la Inclusión: La formación de maestros con pertinencia y en contexto, desde una perspectiva intercultural. In D. Mato (Ed.), *Educación superior, colaboración intercultural y desarrollo sostenible/buen vivir. Experiencias en América Latina* (pp. 183–206). IESALC-UNESCO.

Castaño Cuellar, N. C., & Bravo Osorio, L. M. (2022). Taking care of life from amazonian indigenous cosmogony: Implications for teaching biology as a cultural practice. *Interdisciplinary Journal of Environmental and Science Education*, *18*(3), e2281. https://doi.org/10.21601/ijese/12024

Chevallard, Y., & Bosch, M. (2014). Didactic transposition in mathematics education. In S. Lerman (Ed.), *Encyclopedia of mathematics education* (pp. 170–174). Springer. https://doi.org/10.1007/978-94-007-4978-8_48

Cisterna, C. F. (2005). Categorization and triangulation as processes of validation of knowledge in qualitative investigations. *Theoria*, *14*(1), 61–71. https://www.redalyc.org/pdf/299/29900107.pdf

Cobern, W. W., & Loving, C. C. (2001). Defining "science" in a multicultural world: Implications for science education. *Science Education*, *85*, 50–67. https://doi.org/10.1002/1098-237X(200101)85:1&50::AID-SCE5&3.0.CO;2-G

Collste, G. (2019). Cultural pluralism and epistemic injustice. *Journal of Nationalism, Memory & Language Politics*, *13*(2), 152–163. https://doi.org/10.2478/jnmlp-2019-0008

Constitución Política de Colombia. (1991). Corte Constitucional (Edición de 2015).

Council of Europe. (2008). *White paper on intercultural dialogue. "Living Together As Equals in Dignity"*. Council of Europe.

DANE. (2018). *Results of the national population and housing census*. https://www.dane.gov.co/index.php/en/estadisticas-por-tema/demografia-y-poblacion/grupos-etnicos/informacion-tecnica

Departamento Administrativo Nacional de Estadística (DANE). (2020). *Encuesta de Cultura Política (ECP). Identificación subjetiva de la población campesina 2019*. Departamento Administrativo Nacional de Estadística.

Edelson, D. C. (2002). Design research: What we learn when we engage in design. *Journal of the Learning Sciences*, *11*(1), 105–121. https://www.cs.uic.edu/&i523/edelson.pdf

Edelson, D. C. (2006). What we learn when we engage in design: Implications for assessing design research. In J. Van den Akker, K. Gravemeijer, S. McKenney, & N. Nieveen (Eds.), *Educational design research* (pp. 156–165). Routledge.

Eder, M. L., & Adúriz-Bravo, A. (2008). Explanation in science and science teaching: Philosophical and instructional approaches. *Revista Latinoamericana de Estudios Educativos (Colombia)*, *4*(2), 101–133.

El-Hani, C. N., & Mortimer, E. F. (2007). Multicultural education, pragmatism, and the goals of science teaching. *Cultural Studies of Science Education*, *2*, 657–702. https://doi.org/10.1007/s11422-007-9064-y

El-Hani, C. N., & Souza de Ferreira Bandeira, F. P. (2008). Valuing indigenous knowledge: To call it "science" will not help. *Cultural Studies of Science Education*, *3*, 751–779. https://doi.org/10.1007/s11422-008-9129-6

Encarnación Galindo, M. (2022). Recovery of biocultural memory through environmental education in the community of santa cruz ayotuxco. *Interdisciplinary Journal of Environmental and Science Education*, *18*(3), e2280. https://doi.org/10.21601/ijese/12018

Erinosho, S. Y. (2013). Integrating indigenous science with school science for enhanced learning: A Nigerian example. *International Journal for Cross-Disciplinary Subjects in Education*, *4*(2), 1137–1143. https://doi.org/10.20533/ijcdse.2042.6364.2013.0160

Forzani, F. M. (2014). Understanding "core practices" and "practice-based" teacher education: Learning from the past. *Journal of Teacher Education*, *65*(4), 357–368. https://doi.org/10.1177/0022487114533800

Grimberg, B. I., & Gummer, E. (2013). Teaching science from cultural points of intersection. *Journal of Research in Science Teaching*, *50*(1), 12–32. https://doi.org/10.1002/tea.21066

Guido, S., & Bonilla, H. (2010). Interculturalidad y política educativa en Colombia [Interculturality and educational policy in Colombia]. *Revista Internacional Magisterio*, *46*, 32–35.

Hail, C., Hurst, B., & Camp, D. (2011). Peer debriefing: Teachers' reflective practices for professional growth. *Critical Questions in Education*, *2*(2), 74–83. https://files.eric.ed.gov/fulltext/EJ1047573.pdf

Hoffenberg, R., & Saxton, E. (2015). Scientific explanations: A comparative case study of teacher practice and student performance. *Electronic Journal of Science Education*, *19*(5), 302–319. https://files.eric.ed.gov/fulltext/EJ1188291.pdf

Hsieh, H.-F., & Shannon, S. E. (2005). Three approaches to qualitative content analysis. *Qualitative Health Research*, *15*(9), 1277–1288.

Karner, M. J. (2022). Collective narratives of the Kfarsghabi diasporic community: An important tool to reinstate group solidarity, ethnic identity and societal acceptance. *Journal of Ethnic and Cultural Studies*, *9*(3), 1–26. https://doi.org/10.29333/ejecs/1073

Kennedy, B. L., & Lopez, M. P. S. (2022). Effectively teaching a single course in multicultural education to pre-service teachers. *Teaching & Learning Inquiry*, *10*, 1–53. https://doi.org/10.20343/teachlearninqu.10.19

Kuran, T., & Sandholm, W. H. (2008). Cultural integration and its discontents. *Review of Economic Studies*, *75*(1), 201–228. https://doi.org/10.1111/j.1467-937X.2007.00469.x

López, L., Cataño, N., López, H., & Velásquez, V. (2011). Cultural diversity of Afro-Colombian traditional healers: Preservation and conciliation of knowledge. *Aquichan*, *11*(3), 287–304.

Lowan, G. (2012). Expanding the conversation: Further explorations into indigenous environmental science education theory, research, and practice. *Cultural Studies of Science Education*, *7*, 71–81. https://doi.org/10.1007/s11422-012-9379-1

Ludwig, D., & El-Hani, C. N. (2020). Philosophy of ethnobiology: Understanding knowledge integration and its limitations. *Journal of Ethnobiology*, *40*(1), 3–20. https://doi.org/10.2993/0278-0771-40.1.3

McKenny, S., & Reeves, T. (2012). *Conducting educational design research*. Routledge.

McNeill, K., & Krajcik, J. (2012). *Supporting grade 5-8 students in constructing explanations in science: The claim, evidence, and reasoning framework for talk and writing*. Pearson.

Medin, D. L., & Bang, M. (2013). Culture in the classroom. *Phi Delta Kappan*, *95*(4), 64–67. https://doi.org/10.1177/003172171309500414

Meyer, X., & Crawford, B. A. (2011). Teaching science as a cultural way of knowing: Merging authentic inquiry, nature of science, and multicultural strategies. *Cultural Studies of Science Education*, *6*(3), 525–547. https://doi.org/10.1007/s11422-011-9318-6

Montoya, A. (2020). Representaciones del agua de comunidades campesinas y étnicas en el alto san jorge (Córdoba) y bajo Cauca (Antioquia), Colombia. *Luna Azul*, *51*, 121–150. https://doi.org/10.17151/luaz.2020.51.7

Mpofu, V., Otulaja, F. S., & Mushayikwa, E. (2014). Towards culturally relevant classroom science: A theoretical framework focusing on traditional plant healing. *Cultural Studies of Science Education*, *9*, 221–242. https://doi.org/10.1007/s11422-013-9508-5

Ocoró, A. (2021). The role of the curriculum in the reproduction of ethnic-racial inequalities. A look at the Argentine case from a latin American perspective. *Revista INTEREDU*, *1*(4), 41–68. https://doi.org/10.32735/S2735-65232021000490

Odora, R. J. (2014). Using explanation as a teaching method: How prepared are high school technology teachers in free state province, South Africa. *Journal of Social Sciences*, *38*(1), 71–81. https://doi.org/10.1080/09718923.2014.11893238

OECD. (2010). *Educating teachers for diversity. Meeting the challenge*. OECD Publications.

O'Flaherty, R. M., Davidson-Hunt, I. J., & Manseau, M. (2008). Indigenous knowledge and values in planning for sustainable forestry: Pikangikum first nation and the whitefeather forest initiative. *Ecology and Society*, *13*(1), art6.

Rahmawati, Y., & Ridwan, A. (2017). Empowering students' chemistry learning: The integration of ethnochemistry in culturally responsive teaching. *Chemistry: Bulgarian Journal of Science Education*, *26*(6), 813–830.

Rodriguez, A. J. (2015). What about a dimension of engagement, equity, and diversity practices? A critique of the next generation science standards *Journal of Research in Science Teaching*, *52*(7), 1031–1051. https://doi.org/10.1002/tea.21232

Rodriguez, A. J., & Morrison, D. (2019). Expanding and enacting transformative meanings of equity, diversity and social justice in science education. *Cultural Studies of Science Education*, *14*(2), 265–281. https://doi.org/10.1007/s11422-019-09938-7

Saito, C. H. (2014). Science and education across cultures: Another look at the Negev Bedouins and their environmental management practices. *Cultural Studies of Science Education*, *9*(4), 977–991. https://doi.org/10.1007/s11422-014-9577-0

Sandoval, W. A. (2003). Conceptual and epistemic aspects of students' scientific explanations. *Journal of the Learning Sciences*, *12*(1), 5–51.

Schwartz, S., & Lederman, N. G. (2002). It's the nature of the beast: The influence of knowledge and intentions on learning and teaching nature of science. *Journal of Research in Science Teaching*, *39*(3), 205–236. https://doi.org/10.1002/tea.10021

Sedano, W. (2013). La enseñanza de la química orgánica desde la perspectiva de la interculturalidad. *Nousitz: Revista de investigación científica y tecnológica*, *54*, 821–831.

Seehawer, M. (2018). South African science teachers' strategies for integrating indigenous and Western knowledges in their classes: Practical lessons in decolonisation. *Educational Research for Social Change*, *7*, 91–110. https://doi.org/10.17159/2221-4070/2018/v7i0a7

Seiler, G. (2013). New metaphors about culture: Implications for research in science teacher preparation. *Journal of Research in Science Teaching*, *50*(1), 104–121. https://doi.org/10.1002/tea.21067

Shizha, E. (2007). Critical analysis of problems encountered in incorporating indigenous knowledge in science teaching by primary school teachers in Zimbabwe. *Alberta Journal of Educational Research*, *53*(3), 302–319. https://doi.org/10.11575/ajer.v53i3.55295

Siegel, H. (2014). What's in a name?: Epistemology, "epistemology," and science education *Science Education*, *98*(3), 372–374. https://doi.org/10.1002/sce.21104

Sloane, F. (2006). Normal and design sciences in education: Why both are necessary. In J.van den Akker, *Educational design research* (pp. 9–44). Routledge.

Smith, C. L., & Wiser, M. (2015). On the importance of epistemology–disciplinary core concept interactions in LPs. *Science Education*, *99*(39), 417–423. https://doi.org/10.1002/sce.21166

Snively, G., & Corsiglia, J. (2001). Discovering indigenous science: Implications for science education. *Science Education*, *85*(1), 6–34. https://doi.org/10.1002/1098-237X(200101)85:1&6::AID-SCE3&3.0.CO;2-R

Stagg, S., Jang, S., San Miguel, J., Styres, S., & Madsen, A. (2018). Infusing indigenous knowledge and epistemologies: Learning from teachers in Northern aboriginal head start classrooms. *McGill Journal of Education*, *53*(1), 9506.

Tarozzi, M. (2012). Intercultural or multicultural education in Europe and the United States. In B. Della Chiesa, J. Scott, & C. H. Hinton (Eds.), *Languages in a global world: Learning for better cultural understanding*. OECD Publishing. https://doi.org/10.1787/9789264123557-28-en.

Teo, T. W. (2013). Different perspectives of cultural mediation: Implications for the research design on studies examining its effect on students' cognition. *Cultural Studies of Science Education*, *8*, 295–305. https://doi.org/10.1007/s11422-012-9437-8

Tovar-Gálvez, J. C. (2008). Modelo metacognitivo como integrador de estrategias de enseñanza y estrategias de aprendizaje de las ciencias, y su relación con las competencias. *Revista Iberoamericana de Educación*, *46*(7), 1–9. https://doi.org/10.35362/rie4671916

Tovar-Gálvez, J. C. (2021). The epistemological bridge as a framework to guide teachers to design culturally inclusive practices. *International Journal of Science Education*, *43*(5), 760–776. https://doi.org/10.1080/09500693.2021.1883203

Tovar-Gálvez, J. C. (2022). Acculturation in the integration course for immigrants in Germany: a study from the cultural bridge approach. *Journal of Ethnic and Cultural Studies*, *9*(3), 72–91. https://doi.org/10.29333/ejecs/1061

Tovar-Gálvez, J. C. (2023). Intercultural teaching practices for science education to support teachers in culturally diverse classrooms. *Teaching Education*. Advance online publication. https://doi.org/10.1080/10476210.2023.2167975

Tovar-Gálvez, J. C., & Acher, A. (2019). Relaciones entre la epistemología de las ciencias y las epistemologías tradicionales: Contribuciones a la práctica didáctica, *CIMIE19* (pp. 1–7). AMIE.

Tovar-Gálvez, J. C., & Acher, A. (2021). Design of intercultural teaching practices for science education based on evidence. *Enseñanza de las Ciencias*, *39*(1), 99–115. https://doi.org/10.5565/rev/ensciencias.2891

UNESCO. (2006). *UNESCO guidelines on intercultural education*. UNESCO.

UNESCO. (2008). *Inclusive education: The way of the future*. UNESCO.

Valladares, L. (2011). Un modelo dialógico intercultural de educación científica. *Cuadernos Interculturales*, *9*(16), 119–134.

Van den Akker, J., Gravemeijer, K., McKenney, S., & Nieveen, N. (2006). Introduction to educational design research. In J. Van den Akker, K. Gravemeijer, S. McKenney, & N. Nieveen (Eds.), *Educational design research* (pp. 1–8). Routledge.

van Melle, J., & Ferreira, M. (2022). Developing students' intercultural sensitivity at the home campus: An innovative approach using the theory of the creative action methodology pedagogy. *Teaching & Learning Inquiry*, *10*, 12. https://doi.org/10.20343/teachlearninqu.10.12

Walke, D. (2006). Toward productive design studies. In J. Van den Akker (Ed.), *Educational design research* (pp. 9–18). Routledge.

Wartha, E. J., Silva, E. L. D., & Bejarano, N. R. R. (2013). Cotidiano e contextualização no ensino de química. *Química nova na escola*, *35*(2), 84–91.

Wickman, P.-O. (2004). The practical epistemologies of the classroom: A study of laboratory work. *Science Education*, *88*, 325–344. https://doi.org/10.1002/sce.10129

Windschitl, M., Thompson, J., Braaten, M., & Stroupe, D. (2012). Proposing a core set of instructional practices and tools for teachers of science. *Science Education*, *96*(5), 878–903. https://doi.org/10.1002/sce.21027

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APPENDIX 1: GUIDANCE TOOL FOR PLANNING AFTER ITS REFINEMENT IN THE THIRD CYCLE OF DBR

ITPSE of Planning. Building the Epistemological Bridge	
Task 1	*Propose a daily situation for engaging students in its explanation using diverse epistemologies. The students' learning aim is to participate in both epistemologies. The students' learning output is the explanation of the same situation from each epistemology.*

Prompt 1: epistemology is a system of knowledge or ideas, values and norms, experiences or practices, materials, and devices or instruments that communities use to produce knowledge, goods and services. Science is an epistemology emergent from western culture. Cultures different to the western or westernised have other epistemologies.

Prompt 2: The phenomenon is put into context, presenting it to students as a situation. The situation that students will explain is an event, experience, happening, anecdote or activity of the daily context. The situation must be easily understandable for the students, narrated simply and describe a phenomenon that the students cannot easily explain from any of the epistemologies of the class. In the end, a guiding question motivates students to propose explanations using each epistemology's content. The contents to teach and teaching activities focus on explaining the situation. Remember: context + phenomenon + question.

Situation to explain	
Write here your proposal	
Task 2	*Organize the knowledge and experiences of each culture, as independent content, according to the categories –ideas, production practices, and legitimization practices, to engage students in proposing explanations of the phenomenon described in the situation.*

Prompt 3: an idea is a connection between concepts, values, and practices which has the power to describe or give an account of phenomena. Production practices are all the experiences that communities carry out based on knowledge to originate information, goods, products, services, or new knowledge. For instance, in an indigenous realm, sacred rituals or the elaborations of products (clothes, medicine, ceramic, and others) would be production practices. In science, laboratory procedures are some production practices. Legitimization practices are all the experiences that communities carry out based on rules to support, regulate, normalize, recognize, and disseminate their knowledge and products. Those norms demarcate the domain of each epistemology. For example, in an indigenous realm, communities legitimize (incorporate) knowledge when young people listen to the wisdom of an Elder. In science, communities legitimize (validate) knowledge using standardized protocols to regulate procedures. Remember that each Idea and Practice you plan to teach should provide something for students to explain the study situation. You can also go back and reconsider if the students can explain the proposed situation from those contents (of both epistemologies) and introduce changes.

Prompt 4: you put Epistemological Independence into practice when you define the contents belonging to each culture (ideas and practices). Likewise, it also happens when you give both epistemologies the same relevance for teaching and learning purposes (produce explanations). Finally, you also enact this principle when you address and use such contents with students without mixing them, without explaining one from the other and without evaluating one from the other.

Scientific Idea (SI)	**Traditional Idea (TI)**
Write your proposal	*Write your proposal*
How will the SI help students explain the situation?	**How will the TI help students explain the situation?**
Write your proposal	*Write your proposal*
Scientific Production Practice (SPP)	**Traditional Production Practice (TPP)**
Write your proposal	*Write your proposal*
What information can students collect through the SPP to explain the situation?	**What information can students collect through the TPP to explain the situation?**
Write your proposal	*Write your proposal*
Scientific Legitimation (Validation) Practice (SLP)	**Traditional Legitimation (Incorporation) Practice (TLP)**
Write your proposal	*Write your proposal*

(Continues)

How will the SLP help students explain the situation?	**How will the TLP help students explain the situation?**
Write your proposal	*Write your proposal*

How could I approach with the students the *ideas* of each epistemology *independently* but focused on explaining the situation?

What material or strategies can I use to address the ideas with my students?

What can I do if students find it difficult to understand or use the ideas?

What can I do if my students do not enact *epistemological independence* while using the *ideas* and development of *production* and *legitimation practices*?

Task 3 *Identify similarities between scientific practices and other cultures' practices to engage students in crossing epistemological borders, transiting between epistemologies, and participating in each domain to build explanations*

Prompt 5: the different communities have commonalities in the production of knowledge processes. Some similar or common elements are observation practices, communication practices, regulation norms, values, goals and desires, specific languages, experts, production practices and legitimization practices.

Prompt 6: you put Epistemological Similarity into practice when you identify common elements between different cultures with equivalent goals. Likewise, you achieve this when you engage your students in recognizing such similarities and using them as a reason to transit between epistemologies. For example, observation is a practice used by indigenous, peasant and scientific communities. Although this practice differs for each community-culture (independent in its procedure), the different versions have a similar objective: people use it to collect information about a phenomenon. Communities can use this information to explain a situation.

Example of similarities:

Similarity: Production through experiences (it is an example that you might use)

It relates

Scientific Production Practice (SPP)	**Traditional Production Practice (TPP)**
Planning and developing research…	*Implementing traditional knowledge…*

Why is it a similarity between both epistemologies?

Both communities obtain information and products through experiences. Students can notice that the *production practices* have a similar objective or function, although the experiences are different for each community.

Similarity: Legitimation of knowledge (it is an example that you might use)

It relates

Scientific Legitimation (Validation) Practice (SLP)	**Traditional Legitimation (Incorporation) Practice (TLP)**
Analyzing and interpreting information…	*Sharing traditional knowledge…*

Why is it a similarity between both epistemologies?

Both communities recognize, accept and put into circulation and use knowledge, practices and products according to specific standards. Students can notice that *legitimation practices* have a similar objective or function, although the norms of each community are different.

Your proposal of similarities:

Possible title indicating the process, action, situation, characteristic, value, etc., which is common or similar between both epistemologies

It relates

Scientific aspect	**Traditional aspect**
Write your proposal	*Write your proposal*

Why is it a similarity between both epistemologies?

Write your proposal

Possible title indicating the process, action, situation, characteristic, value, etc., which is common or similar between both epistemologies

It relates

Scientific aspect	Traditional aspect
Write your proposal	*Write your proposal*

Why is it a similarity between both epistemologies?

Write your proposal

What can I do so that students identify the *similarities* and use them to transit between epistemologies voluntarily? For example, when students make comparison charts to write specific words of the language of each community, they can visualise that language is a common feature of different epistemologies. Also, students will understand that languages should not be mixed and possibly be able to consciously switch languages according to context.

Prompt 7: remember that in the whole process of the *Epistemological Bridge*, we have the objective of making use of the principle of *epistemological independence*. Some of the most common mistakes are that students use the language of science, to talk about the traditional, and vice versa. Likewise, it may happen that students use the clothing and tools of the science laboratory to carry out traditional practices. With this in mind, please remember that during the process of participating in practices that are *similar* to each other, *independence* should be preserved.

APPENDIX 2: GUIDANCE TOOL FOR EXPLANATIONS AFTER ITS REFINEMENT IN THE THIRD CYCLE OF DBR

ITPSE of Enactment. Teaching to produce explanations from the epistemological bridge: Situations to be explained	
Write here the situation	
Explanations from each culture	
Conclusion from the Scientific point of view	Conclusion from the Traditional point of view
From what I have learned through the scientific idea and practices, what can I say about the situation to be explained?-how would I answer the question?	*From what I have learned through the traditional idea and practices, what can I say about the situation to be explained?-how would I answer the question?*
Evidence from the Scientific Production Practice	Evidence from the Traditional Production Practice
What data or information did I obtain during the scientific laboratory practice(s)?	*What data or information did I obtain during the traditional elaboration process(es)?*
Results of the Validation of Scientific Knowledge	Results of the Incorporation of Traditional Knowledge
Does the data or information I obtained in the laboratory meet the norms of scientific and social validation? Was there data that was very far from the average? Were the data far from the theoretical value? What data was rejected? What possible mistakes did I make during the laboratory practice? What did I learn from science's social and/or environmental implications?	*Does the data or information I obtained during the elaboration experience meet the traditional rules of the community? Does my way of incorporating new knowledge follow the traditional norms of the community? Did I make changes to how communities share their knowledge? To whom did I share the knowledge? What other ways to share traditional knowledge could I carry out?*
Interpretation from the Scientific Idea	Interpretation from the Traditional Idea
What do the data obtained in the laboratory and the validation process mean if I interpret them from the Scientific Idea? How does this interpretation help me explain the situation from science?	*What do the data obtained in the elaboration and the incorporation process mean if I interpret them from the Traditional Idea? How does this interpretation help me explain the situation from the traditional?*
Similarities between Cultures	
Why are both production practices (scientific laboratory and traditional elaboration) similar?	
Why are both legitimization practices (validation and incorporation) similar?	
What other processes are similar between both ways of constructing knowledge?	

Teachers' feedback