Conceptual Understanding in the Construction of a Technology Concept: A Case Study with Colombian Students

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Abstract

This article presents an analysis of students' conceptual understanding of technology. The study focused on two groups of seventh-grade students located in Bogotá, Colombia, living in rural and urban areas and participating in activities developed in a virtual learning network. The methods used in this study followed grounded theory (Strauss & Corbin, 2002) to generate a theoretical structure that allows explanations to be built on how participants construct concepts. A total of 1,257 analysis units were obtained. After an open, axial selective coding process, these units were classified into four categories: artifacts, materials, and instruments; social and cultural aspects; systems, knowledge and processes; and scientific applications. From these categories, the results show an ordination in transversal dimensions helicoidally articulated in the following ascending order: (1) artifacts (technological, cultural, symbolic, and scientific), (2) objectives of technological advances (transformation processes with varied purposes highlighting continuous technological change), (3) fulfillment of basic survival needs (daily life, welfare, and biological maturity), (4) artifact production in terms of process (creation, innovation, and context transformation), and (5) relationships between human beings and technology (passive role, positive interdependence, and symbiosis). In conclusion, a unidirectional concept of technology encompassing all its features cannot be built. In contrast, students construct the concept in a plural, complex way. The construction of a technology concept at the school level leads to a more comprehensive education in technology in terms of its attitudinal, volitive, and cognitive aspects, which favor cultural technology insertion in schools.

Keywords: concept of technology, education in technology, concept construction, conceptual understanding.

Problem Context

Technology has transformed knowledge production processes and how people communicate and learn in modern societies (DuPuis et al., 2016). Because of these transformations, new generations should be provided with

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education that helps them to adapt to such changes. In particular, education in technology must provide experiences for the effective appropriation of different types of technological advances and provide conceptual and ethical arguments that enrich judgment abilities. This will lead to conscious, functional, and coherent decision-making about the appropriate technologies used to satisfy current social needs (Balkan Kiyici, 2018). Technology education must provide the basic formation to promote the acquisition of technological concepts and a positive assessment of technology (Calderón García, 2015).

A starting point for basic education aimed at acquiring technological concepts is understanding what technology means for young students and how they focus on and construct this concept. Despite the widely recognized importance of the concept of technology, studies on its comprehension are not common (de Vries, 2016), and reflections on the nature of technology in the school context are scarce. Education in technology is widely perceived as the dissemination of technological knowledge in schools or the didactic transposition of technological concepts in conditions similar to those in science teaching (Cajas, 2001). This view ignores the personalized social context from which technology comes and in which it is applied (Järvinen & Rasinen, 2015; Twyford & Järvinen, 2000).

Few studies describe the conceptual understanding of technology, in contrast with the abundance of studies that describe the perceptions and attitudes of young students towards technology (Polino, 2015; Ankiewicz, 2019b). Therefore, it is necessary to set up studies that allow the concept construction pathways used by young students to be identified as well as the characteristics of this process. Based on the aforementioned need for such studies, some questions are formulated in the context of the project entitled Construction of the Concept of Technology in a Virtual Learning Network. This article considers the following research question: What type of concept construction pathways are followed by seventh-grade students when constructing the concept of technology? The aim is to determine the pathways followed by seventh-grade basic education students on the concept of technology during their interactions within a virtual learning network.

Literature Review

Research on education in technology is scarce compared to research focused on education in sciences, where construction processes have been studied for most central scientific concepts (de Vries, 2016). Nevertheless, there are contributions focused on constructing the concept of technology, among which the work of Gustafson et al. (1999) stands out. These authors asked 242 students from Grades 1–5 to propose ideas to enhance the stability of a structure to determine previous concepts on technology. These authors concluded that despite proposing very creative solutions, the students did not know the concepts related to their proposed ideas. In another study, Gustafson et al. (1999)

determined the technological knowledge and problem-solving abilities of 334 children of both genders. In a survey entitled the Awareness of Technology Survey, case studies were assessed before, during, and after classroom implementation. The authors concluded that after classroom activities, the students showed a greater ability to differentiate which ideas were useful or not. For most cases, the simplest solutions for a technological problem were the most useful. However, the students did not identify the concepts used or the classroom experiences that allowed them to find solutions. For future research, Gustafson et al. proposed exploring the concepts of technology and technological design, from which the students would start solving the proposed problems.

Using the same concept of technological problems, Tywford and Järvinen (2000) aimed to explore concept acquisition by 25 fifth-grade students through collaborative environments. Evidence for conceptual comprehension of technology was expected to be evidenced through explanations of the processes performed and the ability to represent such explanations. The study revealed that technological concepts presented in the outlined solutions came from students' experiences, imagination, creative ability, metacognitive processes, analysis, and ability to make spontaneous judgments. The authors concluded that technology comprehension does not necessarily come from classroom knowledge but from experience, reflexive thought, and active participation in problem-solving.

The conclusion above is confirmed by Davis et al. (2002). These authors aimed to identify comprehension, common elements, and variations of technological concepts by 92 students in Grades 2, 4, and 6, applying individual interviews with questions on the aspects of model design and object images. The results showed a progression in the level of conceptual grouping abstraction on artifacts, material identification, and selection related to students' ages. This coincides with the findings of Chatoney (2003; as cited by de Vries, 2016), who asked 6-year-olds to discover the properties of an object set. Children recognized the names of materials but not their properties. Davies et al. (2002) concluded that technological concept construction is linked to particular processes and artifacts; a progression toward more abstract aspects was evidenced in older students. The authors suggested that, for future research, strategies must be designed not to be linked to the solution of problems with definite models (e.g., the bridge used in this research) to enhance the comprehension of abstract technological concepts.

The recommendation of Davis et al. (2002) was implemented by Balkan Kiyici (2018) in her research on 58 fourth-grade students. This author aimed to identify perceptions of technology using drawings, images, metaphors, word association tests, and interviews. The author found that students equated the concept of technology with artifacts that make life easier for human beings.

The common element observed in the results of these studies is the students' total or partial lack of knowledge about technological concepts.

Concepts are generally associated with definite objects and technological artifacts and rarely associated with conceptual aspects requiring a higher abstraction level.

Education in technology has often opted for implementing the results of studies on science teaching (de Vries, 2016). One example is the use of didactic transposition (Chevallard, 1991) to promote the teaching of scientific knowledge in schools. In the field of technology, this approach employs criteria such as the development of technology for all, content quality decreases, coherence of what is thought, and the relevance of learned knowledge for daily life (Cajas, 2001). Although there is a dynamic interaction between science and technology, they preserve their ontological independence and conceptual differences in their objectives, results, and development patterns (Niiniluoto, 2016; Stundenmaier, 1985). Therefore, there are specific technological concepts, and their construction depends on the very nature of technology.

In concept construction, external information generally goes through sense perception and takes place in the subject's cognitive structure (Carretero, 2002) through a constant and dynamic process, allowing them to abstract and generalize object properties (Ausubel et al., 1983). A concept becomes abstract, complex, and potentially meaningful when related to ideas previously established in the cognitive structure. A generic meaning of the new concept arises from this interaction (Molina-Vásquez, 2014) in the specific case of technology. These previous ideas can be images, sounds, sensations, and actions that make up a part of the subject's personal experience (Pacey, 2000).

The construction of technological concepts is present in interactive environments in which practical activities, acquired experience synthesis, and analytical abilities coexist to solve problems and design challenges (Twyford & Järvinen, 2000; Van Breukelen et al., 2017). These concepts are not constructed linearly, going from the abstract to the application (Rossouw et al., 2010). Concept constructions generally start from a definite model, object, or experience, advancing toward an abstract level by identifying different concepts to find context-dependent properties and differentiate them into independent contexts (de Vries, 2016). From a pedagogical perspective, technological concepts are meaningful when they facilitate solving a problem or producing a process, product, or artifact (Davis et al., 2002). Their comprehension is enhanced by conceptual trajectories common to different age ranges that become a knowledge base for students (Jones et al., 2001).

Based on a Delphi study, Rossouw et al. (2010) identified a set of general, unifying technological concepts and teaching contexts, including design, system, modeling, resources and materials, and values (de Vries, 2016). In this regard, Ankiewicz (2019a) recommended an integral view from the philosophy of technology to study the concept of technology from the four dimensions presented by Mitcham (1989): objects, knowledge, activity, and volition.

Pacey (2000) understood technology as systems designed to perform a function and proposed that the starting point for comprehension is *technological practice*, which encompasses organizational, technical, cultural, and ideological dimensions. Together with personal experience, motivations, senses, and nonverbal language, these dimensions integrate into a system that facilitates both participation and the incorporation of nature in the search for technological solutions (Osorio Marulanda, 2007).

A systematic approach to technology (Hughes, 1983; Quintanilla, 1998) contrasts with the more established view that emphasizes its instrumental character among students (de Vries, 2016; González García et al., 1996). The systematic approach also contrasts with the approach to technology as a cultural artifact, which illustrates the structural relationship that material pathways and mediated cultural pathways have with cultural construction processes (Cole, 1999; Medina, 2002).

These approaches are put into context with sociological and historical perspectives such as (a) the social construction of technology (Pinch, 1997; Pinch & Bijiker, 1984), (b) actor-network theory (Latour, 2005), and (c) the system model (Hughes, 1983). In the social construction of technology, technological artifacts are understood as social constructions shaping technology and society (Pinch, 1997; Pinch & Bijiker, 1984). Actor-network theory is based on the relationship between human and nonhuman actants, the transformations occurring in this relationship, and the complex structural network in which world explanations and knowledge production are interwoven (Latour, 2005). In the system model, technology is analyzed from its complex and heterogeneous components, such as physical, technical, legislative, and organizational artifacts, as well as scientific products, research programs, natural resources, and people (Hughes, 1983). The system model also considers all these components' functions together with their role in the design, invention, development, system goal feedback, error correction, control of chaos, and diversity (Molina-Vásquez, 2014).

This brief overview demonstrates a diversity of perspectives for understanding technology, the lack of unanimity on the object of this new discipline, and the disparity of its definitions (Cupani, 2006). These factors hinder the use of a single concept with clear learning dynamics for education in technology, which is not yet replete with the same tradition as other knowledge areas (Gilbert, 1995).

Research Methods

This study followed a hermeneutic interpretive method of qualitative research. The method highlights the importance of meaning above data representativeness and is performed in natural rather than experimental contexts (Hernández Sampieri et al., 2008). Grounded theory, which aims to explain an action, interaction, or specific field from systematically analyzed data, was used for this study (Creswell, 2005; Hernández Sampieri et al., 2008). This analysis results in a theory that is, in turn, applied to a particular context without preconceived theoretical positions (Creswell, 2005; Strauss & Corbin, 2002). The analytical process was performed through coding, theoretical sampling, and data comparison, followed by conceptual coding, category comparison, and theory generation around a central category (Hernández et al., 2011).

Qualitative criteria, such as credibility, transferability, dependence, verifiability, and reliability of results (Ruiz Olabuénaga, 2003), were used from data source triangulation, documentation of situations, information gathering techniques, and independent auditing to guarantee the transferability of results.

The sample comprised 159 seventh-grade boys and girls from two schools, one in the rural area and the other in the urban area of Bogotá, Colombia. Student ages ranged between 11 and 15 years, placing them generally within the concrete operational stage (Ramos Ortega, 2009). Students were provided with computer rooms and internet access. Recognizing the concept of technology is one of the competencies included in the education program for the technology and informatics area (Ministerio de Educación Nacional, República de Colombia, 2008).

The study was performed in five phases, starting with a review of previous research to clarify theoretical elements without defining analysis categories. The second phase involved pedagogical, communicative, technological, administrative, and content design. The design was followed by validation of experts in the virtual learning network (VLN), which is the basis for the didactic strategy that supports the construction of the concept of technology. In the third phase, which comprised data gathering, the VLN was implemented with students, and the information from the obtained records was systematized. In the fourth phase, the information from semistructured interviews and VLN protocols was analyzed. In the fifth and last phase, categories emerging from data were used in theory construction to explain students' pathways when constructing the concept of technology.

Instrumentation

The data-gathering instruments used in this study were interaction protocols of communication and cooperation tools included in the VLN (discussion forums and subgroup wikis) and semistructured interviews extensively performed on randomly selected students to track category characteristics (Hernández Sampieri et al., 2008; Strauss & Corbin, 2002).

An initial questionnaire was administered to students to determine previous conceptions of technology, its features, the problems it addresses, and the competencies it develops. VLN design is based on a constructivist pedagogical model of collaborative and meaningful learning. This model includes didactic strategies such as previous knowledge organizers, challenge solving, conceptual map implementation, hypertexts, and collaborative writing. The challenge presented was to discover the identity of a hidden character from four learning units: in search of our character, problems solved by the character, from the history to the current clues, and the impact of our character (Molina-Vásquez, 2014).

Data Analysis

Data analysis was performed in the AtlasTi platform (Version 7.0), starting with a line-by-line microanalysis of systematized protocols (Strauss & Corbin, 2002). Repeated expressions were eliminated, and 1,257 analysis units were extracted. Open decoding was used to classify analysis units into central codes and subsequently into 40 subcategories referring to technology's conceptual construction. These subcategories represent events, actions, objects, or interactions among data that define the properties and dimensions of a more general category (Strauss & Corbin, 2002). In axial coding, relationships between subcategories were established and grouped into four categories evidencing conceptual construction. These categories allow the identification of causal conditions, actions, and interactions. Selective coding was performed afterward to integrate categories, according to their dimensions, into a theory that explains the pathway followed by students to build the concept of technology.

Results

Analysis of the initial questionnaire results revealed that students identified technology through artifact types: (a) technological (e.g., cell phones and computers); (b) scientific, related to health (e.g., a stethoscope or microscope); (c) abstract symbolic (e.g., communication or satellite waves); and (d) cultural, for the welfare of humans (e.g., utensils or means of transport).

Regarding conceptual construction activities, 40 codes were extracted from Forum 1: Character Evolution, and 50 codes were extracted from Forum 2: Inventory of Needs. Twenty-one codes were extracted from Forum 3: Discovering the Profile, seven codes from Activity 4: Wiki, and 31 codes from the semistructured interviews. Based on their common elements, these codes were grouped into 40 subcategories and posteriorly put into four general categories: (1) artifacts, materials, and instruments; (2) social and cultural aspects; (3) systems, knowledge, and processes; and (4) scientific applications. Those relationships common to general categories allow us to describe the pathways along which the technology concept is constructed, which is understood as steps given and trajectories followed by students.

Table 1 details each category's central aspects, from the initial questionnaire through the learning activities, and concludes with the semistructured interviews. As can be observed in the *artifacts, materials, and instruments* (AMI) category, the students initially alluded to the usefulness of technological artifacts, the materials from which they are made, and their

Table 1

Construction Characteristics for the Concept of Technology

Moments	Categories in the Concept of Technology Artifacts, materials, and instruments (AMI)	Social and cultural aspects (SC)	Systems, knowledge, and processes (SKP)	Scientific applications (SA)
Initial questionnaire Previous concepts	Technological artifacts. Usefulness. Artifact production.	Cultural artifacts. Human welfare.	Symbolic artifacts, designing, inventing.	Scientific artifacts, experimenting, explaining the world.
Activity 1 On the search for our character	Production, advances, and utility of artifacts and materials. Satisfaction of needs.	Relationship: technological advances-human evolution-society. Solving problems of daily life, environmental, and survival.	Development of knowledge. Relationship with the context. Technological process.	Scientists solve problems.
Activity 2 Problems solved by the character	Problems of utility, operation, invention, and modification of artifacts and materials.	Problems of human development, well-being, and quality of life. Daily, environmental, communicational problems and social change.	Problems of evolution of humanity, materials, and knowledge.	Solves health problems.
Activity 3 From history to current clues	Instruments and artifacts satisfy needs.	Solution to daily life problems and facilitating work. Influences the formation of social and ecological consciousness.	Bidirectional relationship between technological advances and human evolution. Invention in artifact modification.	Curing disease.
Activity 4 Impact of our character	Advance of methods used in artifact production.	Positive impact in daily life. Negative impact on the environment.	Technology changes thanks to human needs.	Not recorded.
Interviews In-depth	Artifacts and instruments change through invention and modification process	Social and ecological impact.	Knowledge, innovations, creation, and the human being all comprise technology.	Technology is based in scientific knowledge.

Note. Taken from Table 7 in Molina-Vásquez (2014) found on pp. 246–247.

function. They then referred to the advance of artifacts to satisfy needs and to production means. Last, the students referred to changes in the invention process. Some examples of the expressions used are as follows:

> "As times changed, needs became bigger, and for this reason the production of materials, instruments, and artifacts was growing to improve" (Activity 1—Student 59).

> "The human being needs more artifacts to make life simpler" (Activity 2—Student 14).

These expressions indicate that technology is associated with tangible objects, machines, and artifacts present in students' personal experiences that aim to solve the changing needs of daily life. Attention is focused on the instruments and their production, modification, and advances, whereas the human being is an acritical user.

In the *social and cultural aspects* (SC) category, students first associated technology with quality of life and the relationships between technological advances and human evolution and welfare. Technology was then associated with solving problems in their contexts and environmental incidences, and they could recognize its social and ecological impact. The involvement of human beings and societies in the creation and invention of artifacts becomes evident, as can be observed in the following expressions:

> "It [technology-society relationship] will never end, as we will always have needs and we will always have solutions, and the solution will always be technology and our advantages in knowledge" (Interview—Student 31).

> "Technology looks for an advanced solution to a problem but when one is solved another comes out" (Activity 2—Student 9).

One perspective is that technological advances and developments are determined from a humanistic view linked to interpretative, creative, and imaginative activities that promote material fulfillment. The students claimed that society and technology are interdependent and preserve symbiotic relationships aiming to satisfy needs. In this way, technology is a social phenomenon and, as such, is related to other social phenomena (Geslin, 2000; Rosales Rodríguez, 2006). Furthermore, as a cultural artifact, technology aims to fulfill a human project (Cole, 1999).

In the *systems, knowledge, and process* (SKP) category, the students started by relating technology with project design, invention, and development of knowledge within context. The students then integrated intelligence, innovation, and ingenuity in problem-solving and concluded by claiming that knowledge, the creation process, and humans are all technology components. Example expressions are as follows:

> "It serves to satisfy human being needs. It is an example of technology, invention, innovation" (Activity 2—Student 20).

> "I think that it [technology] is more like creativity, ingenuity, innovation, and not just devices" (Interview—Student 107).

In students' constructions, technology is a complex unity in which artifacts are not isolated from culture; they involve knowledge, organizations, techniques, materials, general experience, intentional agents, objectives, and results. All of these factors are oriented toward solving problems utilizing a product or by transforming a process. This is consistent with the proposals of technological systems (Mumford, 1982; Quintanilla, 1998; Pacey, 2000) and the central aspects of technological knowledge: design and projected thought (Cupani, 2006).

Science application (SA) was the category least repeated in students' expressions. In addition to science application, technology was also associated with curing disease, understanding nature, developing experimental competencies, and improving human health. The following expression provides an example:

> "There are many problems . . . . Technology solves one and other comes out for example diseases technology has looked for many medicines to cure those but when they make a cure for a disease another disease comes out" (Activity 2—Student 149).

In this category, technology materializes scientific knowledge from the understanding of nature and the production of artificial artifacts (Bunge, 1985, p. 231; as cited in Cupani, 2006, p. 353).

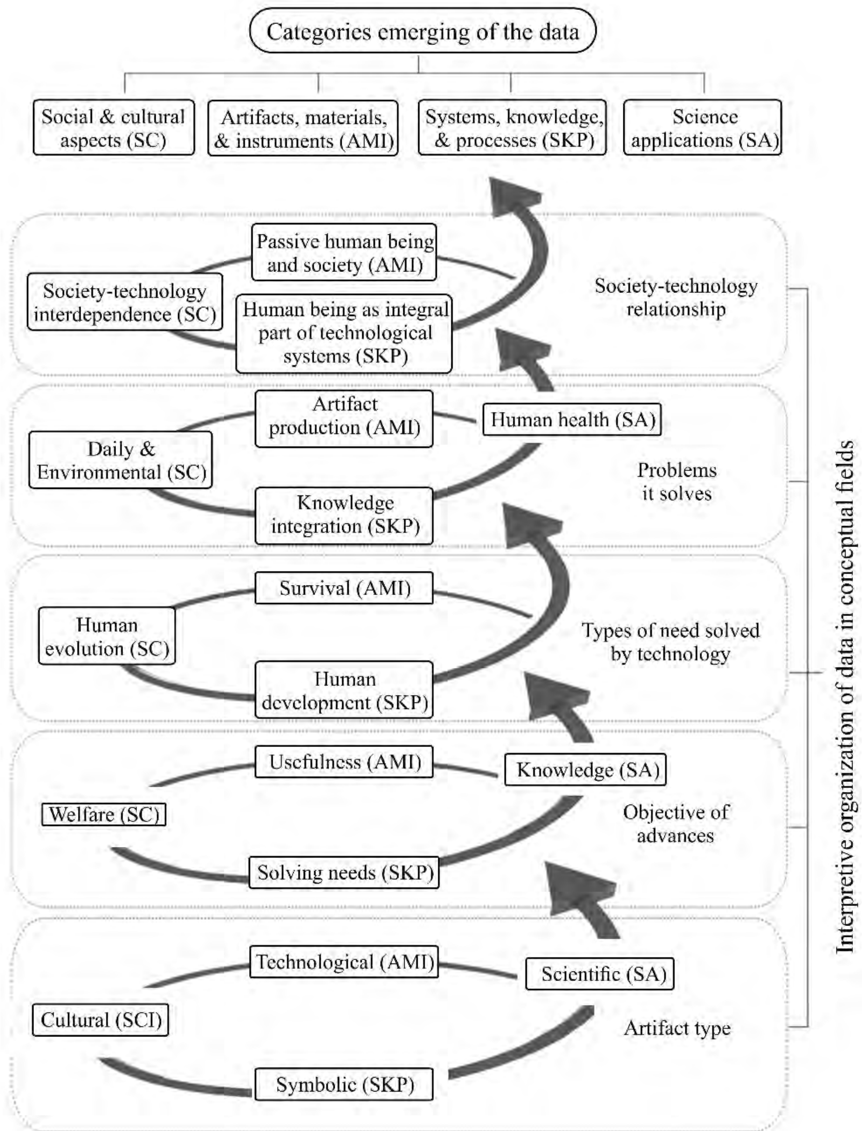
Discussion

A constant theoretical sampling process (a central theory) reveals the relationships among the categories found, their properties, and their dimensions (Strauss & Corbin, 2002). The results demonstrate that a conceptual understanding route departs from personal experiences and advances toward a concept that exhibits complex and multidimensionally interwoven relationships. Therefore, as shown in Figure 1, the conceptual construction route is organized into categories with dimensions, conceptual fields, and relationships. An ascending helicoidal structure, which aims to represent its transformation, is evidenced in the results.

From the categories found (AMI, SC, SKP, SA), *conceptual fields* were articulated that represent their characteristics and transversal relationships:

1. Types of technological, cultural, symbolic, and scientific artifacts were identified.
2. *Objectives of technological advances* include utility, well-being, the satisfaction of needs, and generation of knowledge.

Figure 1
Construction Pathway for the Concept of Technology



3. There is a sense of technology, from the solution of needs associated with survival, daily life, well-being, and those derived from social and cultural contexts.

4. *Problems solved by technology* are daily problems that require transforming the natural context, the production of artifacts and their processes, elements of creation and innovation, the integration of knowledge constructed with human intelligence at the service of the technological process.

5. *Relationships between humanity and technology* extend from unidirectional, passive, positively interdependent ones to those symbiotic and mutually reciprocal involving technology, society, and culture, with diffuse borders.

This organization into categories and conceptual fields is interpreted to construct concepts in the form of a spiral. This pathway moves progressively away from general instrumental perspectives through the appearance of new elements and increasingly complex relationships. First is the concept of instrumental character, as indicated by de Vries (2016), evidencing elements of a concept of technology constructed from the systemic, social, and cultural perspectives and even from the science application perspective. This implies a multidimensional construction of the concept with differentiated elements that, as the conceptual construction progresses, are enriched with the relationships between categories and a technology concept arising from social and cultural aspects.

These findings contrast with several elements exposed in the theoretical framework. The construction of technological concepts in this experience is not linked to specific artifacts and processes (Davis et al., 2002). They are not the product of analytical skills for solving design challenges (Twyford & Järvinen, 2000; Van Breukelen et al., 2017), nor are they linearly constructed from the abstract for application in artifacts' production (Rossouw et al., 2010).

However, the findings coincide with particular aspects reported by Twyford and Järvinen (2000) regarding the fact that conceptual construction is generated from the subject's reflective thinking and their personal experience, together with their technological practice (Pacey, 2000), in relationship with the conception of artifacts that facilitate human life (Balkan Kiyici, 2018). This is oriented toward a conceptual construction of technology that integrates dimensions from objects, knowledge, activity, and volition and is compatible with the conception of technology proposed by Mitcham (1989) and recommended by Ankiewicz (2019a).

Conclusions and Recommendations

This study, conducted in rural and urban areas of the Bogotá region of Colombia, reveals that seventh-grade students' construction of the technology concept is multidimensional and complex. This study articulates and interrelates diverse categories that integrate dimensions of society, culture, systems, instruments, and scientific application. The concept combines relationships among the types of artifacts that comprise technology, the objectives in its advance, the needs it satisfies, the problems it solves, and its symbolic relationships with society and culture. Relationships between categories in the construction of a concept of technology contribute to understanding in the school context, the conceptual appropriation of technology, and the generation of participative spaces, all of which are central aspects of education in technology.

On the other hand, the multidimensional character of the concept of technology sheds light on the nature of technological concepts and the importance of personal experience as a starting point. These elements are enriched from contextual referents that allow taking the concept as a challenge and as a stimulating learning element for technology education. In contrast, the complexity of integration processes becomes an ingredient for the abstraction of the concept.

The results of this work allow a better understanding of the construction pathways of the concept for technology and its relationship with the generation of positive perceptions toward it. Accordingly, the recommendation is to take these results as the starting point for studies involving relationships among attitudinal, methodological, and ontological aspects and, in this way, to determine the characteristics concerning the integral construction of technological concepts.

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