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The Technological Knowledge and Its Typologies

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Abstract

Despite its growing relevance, there is a lack of consensus regarding the typologies of technological knowledge, as well as gaps in the literature on existing classifications. This article presents a systematized review of the typologies of technological knowledge identified in the literature. The research was conducted through a systematized review, encompassing the stages of formulating the research question, developing the protocol, selecting data, synthesizing and analyzing, and presenting the results. Fourteen articles specifically addressing typologies and another ten discussing the characteristics of technological knowledge were identified. The analysis consisted of comparing each typology with the evidenced characteristics, seeking to identify possible relationships between them. The relevance of this research lies in its contribution to the advancement of knowledge in the area, fostering the development of concepts that may have practical and academic implications.

Keywords

Technological Knowledge, Type of Technological Knowledge, Knowledge Sharing

1. Introduction

Technological advancement has established itself as one of the main drivers of economic, social, and scientific transformation. In this context, the concept of technological knowledge emerges as a key element, as it is directly associated with the creation, application, and dissemination of technologies in different sectors. The literature presents multiple interpretations on the topic, sometimes emphasizing the practical dimension of technology, sometimes highlighting its scientific foundation.

Despite its growing relevance, there is a lack of consensus regarding the typologies of technological knowledge, as well as gaps in the systematization of existing classifications. This conceptual fragmentation hinders the construction of solid classification for application in innovation contexts. However, before discussing technological knowledge, it's important to highlight that knowledge has been widely debated over time. For Plato, for example, knowledge was defined as justified and true belief (Zarman, 2018).

Para for empiricists, it is an awareness or familiarity acquired primarily through experience, though not exclusively (Biggam, 2001). Maturana and Varela (1980) understand knowledge as a concrete or conceptual action recognized by an observer; Sajama and Kamppinen (1987) as a set of interpretable information; and Zagzebski (2017) emphasizes the subject's active participation in the acquisition process (Biggam, 2001). Along these lines, Anvari (2011) defines it as accessing and processing structured data.

Beginning in the 19th century, with modern science and the Industrial Revolution, the distinction between scientific and technological knowledge was consolidated (Bunge, 1980; Kuhn, 1996; Feenberg, 1999). Scientific knowledge began to be associated with the study of natural characteristics, based on evidence obtained through systematic methods (Chalmers, 1993). Technological knowledge, initially seen as a mere practical application of scientific knowledge (Bunge, 1980), also came to be understood as capable of formulating its own theories about innovation, capable of existing independently (Cupani, 2006; Freitas Junior et al., 2014; Mirkin, 2018; Stacey et al., 2025). This understanding reinforces its role in socioeconomic development and competitiveness (Porter, 1990; Nelson, 2005).

With its evolution, proposals for typologies emerged that seek to capture the complexity of technological knowledge, considering aspects such as assimilation, justification, technical description of artifacts and role in project development (Norström, 2014).

In this sense, this article aims to conduct a systematized review of the literature on types of technological knowledge, identifying how different authors characterize and classify this construct, which approaches stand out, and how these classifications have evolved over time. Furthermore, the study identifies the relationship between the characteristics of technological knowledge and the development of typologies of this type of knowledge. Based on the literature reviewed, it was possible to suggest three main areas for classifying technological knowledge: the nature of the knowledge, the development process, and its use and practical application. The objective of creating this classification is to provide a consistent theoretical basis for future studies and for the practice of sharing technological knowledge in organizations, in order to better position the theoretical contribution of the study.

2. Technological Knowledge: Characteristics and Concepts

de Vries (2003) highlights that studies on technological knowledge have recently considered its unique characteristics, justifying a comprehensive analysis of its concepts, typologies, and management methods. Authors define it in different, complementary ways, while preserving core aspects. Bohn (1994) describes it as the knowledge necessary to produce goods and services, while de Vries (2003) emphasizes its ability to evaluate how something works, differentiating it from scientific knowledge. Herschbach (1995) reinforces this distinction by associating scientific knowledge with natural characteristics and technological knowledge with human activities.

With the advancement of technology, Mishra and Koehler (2006) expanded the concept to include everything from simple tools to digital resources and the skills to use them. Burgers et al. (2008) related it to the development of products, technologies, and processes, a view expanded by Koehler and Mishra (2009), who emphasized its dynamic and adaptable nature. Houkes (2013) highlighted the knowledge applied to the design and use of artifacts and the systematic methods of engineering. Norström (2014) differentiated tacit knowledge, acquired through practice, from theoretical knowledge, derived from science, both of which focused on technological solutions.

Other perspectives associate it with social problem-solving (Willermark, 2018) and education, such as the ability to apply knowledge in teaching and learning (Scherer, Tondeur, & Siddiq, 2017). Koehler and Mishra (2009) warn that this is a form of knowledge in constant transformation, whose definition quickly becomes obsolete in the face of technological evolution and social demands.

In summary, technological knowledge is applied, interactive, and problem-solving in nature, encompassing conceptual and operational dimensions that explain its production, structuring, communication, and use in different contexts. Some other characteristics of technological knowledge are summarized in **Table 1**.

Table 1. Characteristics and concepts of technological knowledge.

Author(s)	Characteristic	Description
Balconi (2002); Phaal, Farrukh, and Probert (2004); Nieto and Cano (2006); Stacey et al. (2025)	Codification	Technological knowledge can be represented in informational artifacts (reports, manuals, processes, tools) to solve problems and facilitate sharing.
Houkes (2009); Mirkin (2018)	Normativity	Technological knowledge involves value judgments (necessity, suitability, efficiency) about solutions. Not all knowledge qualifies as "justified true belief", and evaluation is an integral part of technology.
Vincenti (1990); Mirkin (2018); Stacey et al. (2025)	Prescriptivity	A characteristic of technological knowledge that guides the process by establishing how to design, produce, and/or operate an artifact. Technical descriptions can support prescriptions.
Mirkin (2018); Houkes (2009); Stacey et al. (2025)	Descriptivity	Possibility of knowledge being described as a technological artifact, being viable to represent its planning, development, and operation.
Houkes (2009); Nieto and Cano (2006); Runyan (2019)	Transmissibility	The degree to which technological knowledge can be communicated and/or shared. The authors emphasize that tacit knowledge requires social and practical interaction for transfer.

Continued

Houkes (2009); Nieto and Cano (2006); Runyan (2019)	Complexity	It involves a lot of information, skills and abilities to generate and apply technological solutions.
Houkes (2009); Nieto and Cano (2006); Runyan (2019)	Dependency	Technological knowledge varies according to its relationship with other knowledge (scientific, organizational) and actors (one or more individuals) necessary for creation.
Houkes (2009); Nieto and Cano (2006); Runyan (2019)	Observability	Ease of identifying and/or deciphering knowledge incorporated in artifacts (design, performance, documentation).
Houkes (2009); Nieto and Cano (2006); Runyan (2019)	Usability	Ability to effectively transform and/or create artificial objects.

Types of Technological Knowledge

Several authors have dedicated themselves to the study of technological knowledge, presenting distinct definitions and approaches on the subject (Bunge, 1980; Bohn, 1994; Herschbach, 1995; de Vries, 2003; Mishra & Koehler, 2006; Burgers et al., 2008; Koehler & Mishra, 2009; Houkes, 2013). These conceptualizations and characteristics of technological knowledge demonstrate its complexity and relevance, which have stimulated the proposal of typologies capable of identifying gaps and opportunities, favoring technological advancement and driving innovation (Teece, 1998).

Taxonomies, typologies, and schemas are essential tools for constructing knowledge maps, which help locate consolidated information and position new knowledge within the existing context (Lambe, 2007; Staddon, 2022). Regardless of the focus, these structures promote dialogue between different perspectives, allowing concepts with different names in certain contexts to be recognized as equivalent in others (Kiesler, 2020). Based on the selected literature, the typologies will be presented according to their authors in **Table 2**.

Table 2. Typologies of technological knowledge.

Authors	Type of technological knowledge	Description
Vincenti (1984)	Descriptive knowledge	It represents aspects “as they really are”; it is assessed for its veracity and rarely changes.
	Knowledge	It defines “how things should be” to achieve objectives, is assessed for efficiency, and can change when efficiency becomes unsatisfactory.
	Tacit knowledge	Acquired through practice or experience, it is difficult to formalize and can be partially represented by diagrams and similar resources.
Vincenti (1990)	Fundamental design concepts	They identify the understanding of the artifact’s operation that guides the design.
	Criteria and specifications	Qualitative and/or quantitative goals.
	Theoretical tools	Theories and conceptual methods necessary for the design process.
	Quantitative data	Results of experiments and/or observations on the project being developed, in the form of tables and graphs.
	Practical considerations	Expertise of designers and users incorporated into the process.
	Design tools	Tools that enable creative thinking and guide expected results.

Continued

Ihde (1997)	Knowledge about technologies	Understanding how the artifact is constructed and its functional aspects.
	Theoretical technological knowledge	Laws and principles (physical/chemical/electrical) that make the artifacts work.
	Knowledge through technologies	Knowledge that emerges from practical application of technological instruments.
Ropohl (1997)	Technological laws	They organize theoretical knowledge into practical generalizations proven by their successful application.
	Functional rules	Practical step-by-step guides to achieving objectives through the use of flowcharts, diagrams, and tables.
	Structural rules	Support for the development and maintenance of technologies, ranging from defining functionalities to the creative design of new artifacts.
	Technical know-how	Practical experience skills are difficult to systematize and often require a long period of time to consolidate.
	Socio-technological understanding	In addition to technical aspects, they consider the interactions between technology, the environment, and society. They recognize that an invention also influences the ecological, social, and even psychosocial context in which it will be inserted, requiring an integrated perspective from those involved.
de Vries (2003)	Physical nature knowledge	Properties and characteristics of the artifact's materials.
	Functional nature knowledge	The form or construction process of the artifact according to its purpose.
	Means-ends knowledge	Combines physical and functional dimensions to inform the selection of materials and design methods when conceiving the artifact.
	Action knowledge	Steps and procedures to complete the artifact's development.
Hansson (2013)	Tacit knowledge	It can be transferred through imitation or learning, and is articulated in three ways: computerization, teaching-learning, and work control and organization.
	Practical rule knowledge	Rules for technical teaching and learning; they can emerge from the tacit, simplify or combine science, or adapt user experiences.
	Technological science	Systematic study of technological solutions, based on experiments.
	Applied natural science	Using natural sciences to create technologies, theory helps resolve practical errors.
Runyan (2019)	Design knowledge	Planning and designing artifacts (design module).
	Making knowledge	Developing and integrating new knowledge (knowledge module).
	Operate and use knowledge	Practical application to meet specific objectives (use module).
Nordlöf, Hallström, and Höst (2022)	Technical skills	Task execution and tool use prioritize what works over why it works, with know-how frequently conveyed through practical demonstrations.
	Technological scientific knowledge	It draws on engineering traditions and the scientific method, requiring an understanding of how processes, activities, and artifacts work, combining standards and practices with technical analysis.
	Socio-ethical technical understanding	Technology-society relationships encompass a critical and multidisciplinary perspective that considers historical, sociological, political, and ethical aspects.

Continued

Staddon (2022)	Practical knowledge	Intuitive execution of activities, without formal rules or explicit reflection on the procedures adopted.
	Structural knowledge	Experience-based knowledge involving understanding, application, analysis, and evaluation; a more reflective and systematic orientation
	Computer science knowledge	Programming and software solutions require the integration of technical and conceptual skills. This presupposes mastery of prior practical and foundational knowledge.

In his study of innovation in the aeronautical industry, Vincenti (1984) examined the learning processes involved in technological development and identified that core ideas already existed, whereas production techniques were refined empirically through trial and error. Thus, the author suggested three main categories of technological knowledge: descriptive—which portrays activities and aspects as they are, is assessed for veracity, and rarely changes; prescriptive—which defines how things should be to achieve a given objective, is evaluated for efficiency, and is subject to change when efficiency proves unsatisfactory; and tacit, difficult to formalize and acquired through practice and experience yet partially codifiable in diagrams and related instructional materials (Vincenti, 1984).

In 1990, Vincenti describes the experience of American engineers, designers, and manufacturers in the aircraft industry and the challenges they face. The author concludes that as technological knowledge accumulates, the variations required to achieve a given objective evolve, as judgment is facilitated and the accumulation of technological knowledge stimulates innovation.

Vincenti (1990), as an engineer in this environment, can identify six categories of technological knowledge: fundamental design concepts, which express the understanding of how the artifact works; criteria and specifications, which establish feasible qualitative and quantitative goals, including requirements and parameters that an artifact must meet, such as dimensions, performance, safety margins, environmental limits, and constraints; and theoretical tools, composed of theories and conceptual methods necessary for the process. Added to these aspects are quantitative data, obtained through experiments or observations, usually represented in tables or graphs; practical considerations, which incorporate the expertise of designers and users; and design tools, which enable creative thinking and guide the artifact's expected results (Vincenti, 1990).

Ihde (1997) argues that all knowledge is interpreted based on pre-existing knowledge and that its results must be subjected to critical approaches. From this perspective, the author proposes three types of technological knowledge: knowledge about technology, theoretical technological knowledge, and knowledge through technologies.

Technological knowledge refers to engineers' and technicians' understanding of how an artifact is constructed and its functional aspects. Theoretical technological knowledge encompasses the physical, chemical, or electrical laws and principles that enable artifacts to function and is essential for scientists and engineers involved in their development. Knowledge through technologies emerges from practice, when individuals apply technological tools to their activities.

Ihde (1997) warns against interpreting this kind of knowledge as a form of "technological salvation" capable of simplistically resolving human deficiencies and problems. Although he argues that scientific knowledge depends on technological advancement, the author emphasizes that the theory of knowledge is mutable and is continually constructed in relation to the technological instruments available.

Ropohl's (1997) typology presents the characteristics of knowledge and, based on these, outlines a classification of knowledge types that, according to him, helps determine which technological knowledge is appropriate for technological education. In this context, the classification initially consisted of four types, but the author added a final type to mitigate the crisis in technological development that existed at the time.

The first type, the author called technological laws, organizes theoretical knowledge into practical generalizations proven by their successful application. Functional rules describe, in a practical manner, the step-by-step process required to achieve a goal, often represented by flows, diagrams, or tables (Ropohl, 1997). The type he called structural rules supports the development and maintenance of technologies, ranging from the definition of functionalities to the creative design of new artifacts. The third type, know-how, represents the set of skills acquired through practical experience, which is difficult to systematize and often requires a long period of time to consolidate. Finally, the sociotechnological understanding, proposed by Ropohl (1997), expands the analysis beyond technical aspects, also considering the interactions between technology, environment, and society. This perspective recognizes that an invention influences not only the technical sphere but also the ecological, social, and even psychosocial context in which it will be inserted, thus requiring an integrated vision on the part of inventors and society.

de Vries (2003) uses empirical data to identify characteristics of technological knowledge that allow for the construction of a typology, relating them to the nature of the artifacts existing at the time of his research. He argues that technological knowledge cannot be defined according to the terms of "justified true belief", as this concept does not encompass all its forms.

Based on a case study, de Vries (2003) proposes a taxonomy based on the nature of artifacts, distinguishing between physical and functional aspects. Physical knowledge refers to the understanding of the properties and characteristics of the materials used in the development of an artifact, while functional knowledge concerns the form or process by which the artifact is constructed, considering the intended purpose.

The author also describes two additional types: means-ends knowledge, a combination of physical and functional knowledge, allows for the selection of materials and methods for designing and designing an artifact; and action knowledge involves understanding the steps and procedures necessary to complete the development of the artifact (de Vries, 2003).

Hansson (2013), studying the educational system, seeks to identify the types of technological knowledge needed by educators and highlights the difficulty teachers have in mastering all the categories he defines. Tacit knowledge has three focuses: articulation through computerization and programming; its role in teaching and learning, given the difficulty of materializing professional experiences; and its use for work control without compromising the quality of life or the interests of workers. He argues that contrary to the view that tacit knowledge should not be disclosed, its transmission and evaluation can improve it.

Another type of knowledge addressed is practical rules, related to technical teaching and learning, especially in practical activities. These rules can arise from the articulation of tacit knowledge, from simplification or combination with scientific knowledge, or even from adaptation to user experiences. Technological science is defined as the systematic study of technological solutions, based on experiments, and is complemented by applied natural science, present in universities and responsible for developing new technologies based on scientific knowledge from areas such as physics, chemistry, biology, and behavioral sciences (Hansson, 2013).

Finally, Hansson (2013) explains that applied natural science has historically extracted information from nature to understand it and, currently, directs this knowledge to create technologies. Even with the routine use of technologies and tacit or practical knowledge, errors can occur, making it essential to draw on scientific theories or understand the basic scientific foundations of applied solutions.

Runyan (2019) analyzes previous classifications of technological knowledge and proposes a new module-based approach. According to the author, by considering technological artifacts as direct results of technological development, modularity theory offers a more efficient path for creating projects aimed at producing new artifacts. This perspective facilitates the organization and application of the different types of knowledge involved in the innovation process.

To develop his reclassification proposal, Runyan (2019) draws on contributions from authors such as Carpenter (1974), Vincenti (1990), Ropohl (1997), and de Vries (2003). Based on this theoretical framework, the author structures technological knowledge into three main modules: project knowledge, responsible for planning and conception; creation of knowledge modules, aimed at the development and integration of new knowledge; and use of knowledge, which involves practical application to meet specific objectives. Modules do not operate in isolation, but constantly interact, which enhances the creation of new technological artifacts, combining both existing knowledge and that generated during the development process. Thus, modularity presents itself as a dynamic and adaptable model for understanding and applying technological knowledge (Runyan, 2019).

Nordlöf, Hallström, and Höst (2022) emphasize that technological knowledge classifications are developed for specific contexts and that comparing them is complex due to the particularities of each application. Based on this analysis, the authors suggest a new categorization focused on technological education, organized into three categories: Technical Skills, Scientific and Technological Knowledge, and Socio-Ethical Technical Understanding.

Technical skills focus on the execution of tasks and the use of tools, emphasizing what works rather than why it works, and are often conveyed through practical demonstrations. Scientific and technological knowledge, in turn, is based on engineering traditions and the scientific method, requiring an understanding of how processes, activities, and artifacts work, combining standards and practices with technical analysis (Nordlöf, Hallström, & Höst, 2022). The socio-ethical technical understanding, in turn, focuses on the relationship between technology and society, encompassing a critical and multidisciplinary perspective that considers historical, sociological, political, and ethical aspects. This approach seeks to understand and discuss the influence of technology on social life, promoting reflections on the impacts and reciprocities between technological advances and social transformations over time (Nordlöf, Hallström, & Höst, 2022).

Staddon (2022) conducted a survey with students to identify how the types of technological knowledge described in the literature manifest themselves in their understanding. Participants were asked what they understood by technological knowledge, and based on their responses, compared with theoretical frameworks, the author identified three predominant types: practical knowledge, structural knowledge, and computer science knowledge.

Practical knowledge was associated by students with the intuitive execution of activities, without following formal rules or explicitly reflecting on the procedures adopted. Structural knowledge was described as knowledge acquired through experience and requiring skills of understanding, application, analysis, and evaluation, demonstrating a more reflective and systematic nature (Staddon, 2022).

Finally, computer science knowledge was associated with the development of technological solutions, such as software programming, requiring the integration of technical and conceptual skills. According to Staddon (2022), this type of knowledge generally depends on prior mastery of practical and structural knowledge, which serves as a basis for the creation and application of computational solutions.

3. Methodology

The research was conducted according to the principles of a systematized literature review to ensure methodological rigor and transparency in the collection and analysis process (Macedo, 2022), in five phases as shown in **Figure 1**.

Source: Authors.

Figure 1. Process of defining the major areas of technological knowledge typologies.

The first step in the review was defining the research question that would guide the study. Thus, the article presents a review of the evolution of typologies of technological knowledge, seeking to answer the question: Is there a relationship between the characteristics of technological knowledge and the typologies defined by different authors?

The databases used were SCOPUS, Web of Science, and Emerald, and the descriptors applied were "types of technological knowledge" and "technological knowledge". Table 3 presents the protocol used, summarizing the search strategy and the number of articles found in the research.

Table 3. Relationship.

Database	Search strategy	Number of articles
Scopus	TITLE-ABS-KEY ("types of technological knowledge") AND PUBYEAR > 2020 AND PUBYEAR < 2025 AND (LIMIT-TO (OA, "all"))	3
Scopus	TITLE-ABS-KEY ("types of technological knowledge") AND (LIMIT-TO (OA, "all"))	4
Web of Science	TS = ("tipos de conhecimento tecnológico") AND PY = (2020-2025)	1
Web of Science	TS = ("types of technological knowledge")	2
Emerald	"types of technological knowledge"	0
Emerald	"types of technological knowledge"	1
Scopus	TITLE-ABS-KEY ("technological knowledge") AND PUBYEAR > 2019 AND PUBYEAR < 2026 AND (LIMIT-TO (OA, "all") OR LIMIT-TO (OA, "Technological Knowledge") OR LIMIT-TO (OA, "all")) AND (LIMIT-TO (EXACTKEYWORD, "Technological Knowledge"))	113
Scopus	TITLE-ABS-KEY ("technological knowledge") AND (LIMIT-TO (OA, "all") OR LIMIT-TO (OA, "Technological Knowledge") OR LIMIT-TO (OA, "all")) AND (LIMIT-TO (EXACTKEYWORD, "Technological Knowledge"))	203
Web of Science	TS = ("technological knowledge") AND PY = (2020-2025)	59
Web of Science	TS = ("technological knowledge")	215
Emerald (2020-2025)	Abstract: "technological knowledge"	3
Emerald	Abstract: "technological knowledge"	6

Inclusion criteria were based on open-access, peer-reviewed articles that explicitly presented typologies of technological knowledge. Exclusion criteria included publications that addressed technology tangentially, without addressing the nature of technological knowledge; duplications; and opinionated texts. The search period was initially established between 2020 and 2025; it was later expanded without a timeframe due to low representativeness.

In the data selection phase, it was agreed that of the 241 non-duplicated articles, 14 dealt specifically with typologies and 10 addressed the characteristics of technological knowledge, constituting the corpus of the research.

Analysis procedures consisted of exploratory reading of abstracts, selection of articles aligned with the research objectives, and systematization of the identified typologies. This process allowed for a historical and conceptual overview of the different classifications of technological knowledge, enabling comparisons between authors and contexts.

Finally, content analysis consisted of comparing each typology with the characteristics highlighted to identify possible relationships between them.

4. Relationship between Typologies of Technological Knowledge and Characteristics of Technological Knowledge

The analysis of technological knowledge can be enriched by relating its typologies (Hansson, 2013; Ihde, 1997; Nordlöf, Hallström, & Höst, 2022; Ropohl, 1997; Runyan, 2019; Staddon, 2022; Vincenti, 1984, 1990; de Vries, 2003) with its characteristics (Balconi, 2002; Houkes, 2009; Mirkin, 2018; Nieto & Cano, 2006; Phaal, Farrukh, & Probert, 2004; Runyan, 2019; Stacey et al., 2025; Vincenti, 1990). This integration allows us to identify conceptual and operational convergences, expanding theoretical understanding and the potential application of this knowledge to innovation and technological management.

To present this relationship, **Table 4** presents the author and their typology. The characteristics present in each typology of technological knowledge are described and presented in **Table 4**. In the description, each characteristic of the type of technological knowledge used in the creation of the identified type is represented by a different color-coded: (C)odification, (N)ormativity, (P)rescriptivety, (D)escritivety, (T)ransmissibility, Comple(X)ity, D(E)pendence, (O)bservability, (U)sability.

Table 4. Relationship between typologies of technological knowledge and characteristics of technological knowledge.

Author	Typology category	Associated characteristics	Description
Vincenti (1984)	Descriptive knowledge	Descriptivity, observability.	It describes the artifact "as is" (D) and becomes visible in the implementation of the technological artifact (O).
	Prescriptive knowledge	Prescriptivity, normativity.	It defines the functionalities and requirements necessary for the artifact's performance (P), involving judgment about the adequacy and efficiency of the knowledge (N).
	Tacit knowledge	Low codification, low observability, low transmissibility, low dependence	The implicit nature of this type of knowledge makes it difficult to meet the characteristics, making its formalization (C) (O) and sharing (T) (O) more complex.
Vincenti (1990)	Fundamental design concepts	Normativity, prescriptivity, usability	They establish desirable standards and properties (N), offer practical guidelines (P) and are applicable when designing (U).
	Criteria and specifications	Normativity, prescriptivity	They ensure appropriate parameters (N) and provide clear execution instructions (P).
	Theoretical tools	Codification, complexity, observability	They can be formalized through models and methods (C), require a high degree of abstraction (X), and can be visualized through simulations and conceptual artifacts (O).

Continued

	Quantitative data	Codification, observability, usability, descriptivity, prescriptivity	They allow for formal representation (C) and measurable visualization of artifact properties (O). The data are useful because they support decisions (U), in addition to describing properties and guiding adjustments to the artifact (D) (P).
	Practical considerations	Usability, dependence, observability	They convert experience into practical applications (U), require knowledge exchange (E), and are perceptible in the performance of prototypes and/or products (O).
	Design tools	Codification, transmissibility, usability, observability	They can be formalized (C), shared (T), and directly applied (U). They are verifiable in the processes and artifacts developed (O).
Ihde (1997)	Knowledge about technologies	Normativity, descriptivity, usability	It involves criteria and standards that define proper design or operation (N), describes the properties and operating modes of devices (D), and is applied to create, maintain, or improve technological artifacts (U).
	Theoretical technological knowledge	Codification, normativity, descriptivity, complexity.	It is formalized in models, formulas, and technical documents (C), establishes parameterized objectives (N), describes properties and attribute representation (D), and, finally, integrates diverse areas of knowledge and has a high level of abstraction (X).
	Knowledge through technologies	Transmissibility, codification, usability, dependence	It can be shared (T), since the experience gained is recorded (C) and results from application to action (U). It is conditioned by the specific characteristics of the technologies and the context of application (E).
Ropohl (1997)	Technological laws	Usability, observability, transmissibility, codification	It transforms knowledge into practical solutions (U), envisions its effects on technology performance (O), and can be taught (T) and applied in different contexts through formalization (C).
	Functional rules	Normativity, prescriptivity	It establishes performance standards and desirable goals (N) and guides process execution and the construction of devices in a structured manner (P).
	Structural rules	Normativity, descriptivity	It defines criteria for the structure and assembly of artifacts (N), in addition to representing components and relationships in detail (D).
	Technical know-how	Observability, usability, dependence	It can be observed in the behavior of users and artifacts (O), and is practical knowledge applied to tasks (U) and requires interaction with other knowledge and collaboration between different competencies (E).
	Socio-technological understanding	Complexity, normativity, dependence	It involves multiple dimensions and variables (X) and considers value judgments and interdisciplinary dialogue (N). Furthermore, it requires dialogue between technical, social, and cultural impacts (E).

Continued

de Vries (2003)	Physical nature knowledge	Normativity, descriptivity	It defines ideal standards for the artifact's physical structure (N), as well as details the elements and arrangements that make up the technology, allowing them to be differentiated from natural or social phenomena (D).
	Functional nature knowledge	Normativity, prescriptivity	It specifies objectives and desirable performance parameters (N) and guides how the artifact should be designed or operated to achieve these functions (P).
	Means-ends knowledge	Dependence, complexity, codification	It integrates knowledge and actors (E), involves multiple variables (X), and can be formalized to facilitate application (C).
	Action knowledge	Observability, usability, codification	It is identifiable in the behavior and use of the technology (O), enables the practical application of the artifact (U), and can be documented in manuals and procedures (C).
Hansson (2013)	Tacit knowledge	Baixa transmissibility, low codification, complexity, dependence	Diffusion (T) is difficult because it is rooted in experience and skills that are difficult to generalize and materialize (C). Application can be influenced by various factors (X) and requires a relationship with another knowledge (N).
	Practical rule knowledge	Observability, descriptivity, transmissibility	Procedures and conditions are observed in the actions of practitioners (O), may have detailed procedures and conditions (D), and can be taught formally and/or informally (T).
	Technological science	Normativity, prescriptivity, complexity, dependence, codification	It establishes quality and performance parameters (N), guides the implementation of solutions (P), presents several technical variables (X), links to other fields of activity (E), and formalizes results (C).
	Applied natural science	Normativity, dependence, observability, descriptivity, usability	It defines application standards (N), demands interdisciplinary integration (E), results in measurable effects (O), characterizes phenomena and processes (D), and ultimately transforms knowledge into solutions (U).
Runyan (2019)	Design knowledge	Normativity, descriptivity, observability	It defines ideal parameters and quality criteria (N), characterizes the project's technical attributes (D), and is visible in the product and/or technical representations (O).
	Making knowledge	Normativity, prescriptivity, codification, transmissibility, complexity	It seeks to meet standards and goals (N), offer clear development guidelines (P), enable recording and systematization (C), can be disseminated among professionals (T), and involves technical, conceptual, and contextual variables in the creation of concrete solutions (X).
	Operate and use knowledge	Codification, dependence, usability	It requires documentation and technical records (C), requires interaction with other knowledge (E), and converts information and skills into functional results (U).

Continued

Nordlöf, Hallström, and Höst (2022)	Technical skills	Observability, usability, complexibilidade, baixa codification	Identifiable in task execution (O), applicable in problem-solving (U), dependent on practical adaptation in different contexts (X), and not always well formalized (C).
	Technological scientific knowledge	Normativity, complexity, descriptivity	Meets scientific and technological criteria (N), integrates theories, methods, and multidisciplinary analyses (X), and details phenomena and properties of technological systems based on scientific principles (D).
	Socio-ethical technical understanding	Transmissibility, codification, dependence, usability	Communicable (T) and documentable in standards and/or guidelines (C), requires dialogue between departments (E), and supports decisions that balance technical feasibility and social responsibility (U).
Staddon (2022)	Practical knowledge	Observability, dependence	Manifested in the execution of tasks and the performance of concrete activities (O), it requires interaction with other knowledge and collaborative practices (E).
	Structural knowledge	Observability, complexity, dependence, normativity, descriptivity	It analyzes operation and behavior (O), involves many interdependencies between variables (X), demands integration with other knowledge (E), follows standards and performance requirements (N), and details elements and relationships that support the analyzed structure (D).
	Computer science knowledge,	Prescriptivity, normativity, complexity, transmissibility, codification, usability	It proposes methods and rules for creating or optimizing technologies (P), follows standards and best practices (N), applies a variety of languages, architectures, and processes (X), is teachable (T), formalizable through code and specifications (C), and can be applied directly to the development and implementation of technological solutions (U).

4.1. Typology of Vincenti (1984) and Associated Characteristics

Vincenti (1984) classifies technological knowledge into three main categories. Descriptive knowledge is directly associated with the descriptive characteristic of this type of knowledge and its observability, as it manifests itself in the implementation of the technological artifact. Prescriptive knowledge is related to prescriptivity and normativity, as it involves defining the functionalities and requirements necessary for the artifact's performance. Tacit knowledge, due to its implicit nature, has difficulty meeting the characteristics of codification, observability, transmissibility, and dependency, making its formalization and sharing more complex.

4.2. Typology of Vincenti (1990) and Associated Characteristics

In Vincenti's (1990) typology, fundamental design concepts are linked to normativity, as they define desirable standards and properties; to prescriptivity, as they offer practical guidelines; and to usability, as they guide the effective application of knowledge in the design process. Criteria and specifications reinforce normativity, ensuring appropriate parameters, and prescriptivity, as they provide clear execution instructions. Theoretical tools are related to their codifiability, due to the possibility of concrete representation; to their complexity, due to the high level of abstraction required; and to their observability, when expressed in simulations or conceptual artifacts.

Quantitative data are codifiable, due to their formal representation; observable, because they derive from measurable phenomena; usable, when they support decisions; and have a descriptive and prescriptive nature, when they describe properties and guide adjustments to the artifact. Practical considerations are highlighted by their usability, when they are converted into solutions; by their dependency, because they require the exchange of experiences; and by their observability, identified in the performance of prototypes or products. Design tools are codifiable, due to their formalization; transmissible, because they enable sharing; usable, because they are directly applied in development; and observable, when they manifest themselves in the processes and artifacts created.

4.3. Typology of Ihde (1997) and Associated Characteristics

In Ihde's (1997) typology, knowledge about technology is connected to normativity, as it involves criteria and standards that define what is considered good design or proper functioning; to descriptivity, describing the properties and modes of operation of devices; and to usability, applied to creating, maintaining, or improving technological artifacts.

Technological theoretical knowledge is linked to normativity, as it defines parameters to be achieved; to descriptivity, through the description of properties and representation of attributes; to complexity, through the high level of abstraction and integration of different areas of knowledge; and to codification, through formalization in models, formulas, and technical documents for systematization and transmission. Knowledge through technologies is related to transmissibility, as it can be shared; to codification, when the experience acquired is recorded; to usability, when it is directly applicable to action; and to dependency, this knowledge is conditioned by the specific characteristics of the technologies used and the context of application.

4.4. Typology of Ropohl (1997) and Associated Characteristics

In the typology proposed by Ropohl (1997), technological laws are associated with Usability, by transforming knowledge into practical solutions; Observability, by identifying its effects on technology performance; Transmissibility, by the possibility of teaching and applying them in different contexts; and Codification, by being formalized for dissemination. Functional rules are linked to normativity, by establishing performance standards and desirable goals, and to prescriptivity, by guiding the execution of processes and the construction of devices in a structured manner.

Structural rules are linked to normativity, by defining criteria for the structure and assembly of artifacts, and to descriptivity, by representing components, connections, and relationships in detail. Know—how is related to Observability, by manifesting itself in the behavior of users and artifacts; to Usability, by its direct application to tasks; and to Dependence, by requiring interaction with other knowledge and collaboration between different competencies. Socio-technological understanding is linked to Complexity, as it involves multiple dimensions and variables; to normativity, as it includes value judgments and impact assessment; and to Dependence, due to the need for dialogue between technical, social and cultural areas.

4.5. Typology of de Vries (2003) and Associated Characteristics

The typology presented by de Vries (2003) presents physical nature as its first type. This type is linked to normativity, as it establishes ideal standards for the physical constitution of the artifact, and to descriptivity, which details the elements and arrangements that make up the technology, allowing them to be differentiated from natural or social phenomena. The functional nature type is connected to normativity, as it defines objectives and desirable performance parameters, and to prescriptivity, as it guides how the artifact should be designed or operated to achieve these functions.

Means-end knowledge is related to Dependence, as it requires interaction between different knowledge and actors; to Complexity, due to the multiplicity of variables involved; and to Codification, as it can be formalized to facilitate its application. Action knowledge is associated with Observability, as it can be identified in the behavior and use of technology; to Usability, which enables the practical application of the artifact; and to Codification, which records actions in manuals, for example.

4.6. Typology of Hansson (2013) and Associated Characteristics

In Hansson's (2013) typology, tacit knowledge presents low transmissibility and difficulty in codification, as it is rooted in personal experiences and skills. It is associated with Complexity, due to the multiplicity of factors that influence its application, and with Dependence, due to its relationship with another knowledge. Knowledge of practical rules is observable, as it manifests itself in the behavior and actions of practitioners; it is descriptive, as it details procedures and conditions; and it presents transmissibility and can be taught formally or informally.

Technological science is linked to normativity, by establishing quality and performance parameters; to prescriptivity, by guiding the implementation of solutions; to Complexity, by the variety of technical variables; to Dependence, by the connection with other fields; and to codification, by the formalization of results. Applied science, on the other hand, is related to normativity, by defining application standards; to Dependence, by requiring interdisciplinary integration; to Observability, by visible and measurable results; descriptivity, by characterizing phenomena and processes; and Usability, by transforming knowledge into concrete solutions.

4.7. Typology of Runyan (2019) and Associated Characteristics

In Runyan's (2019) typology, design knowledge is associated with normativity, by defining ideal parameters and quality criteria; descriptivity, by characterizing the project's technical attributes; and Observability, by enabling its identification in the product's implementation or in technical representations. Knowledge creation is linked to normativity, by seeking to meet standards and goals; prescriptivity, by offering clear development guidelines; codification, by the possibility of recording and systematization; Transmissibility, by enabling its dissemination among professionals; and Complexity, by involving technical, conceptual, and contextual variables in transforming ideas into concrete solutions. Knowledge use is related to codification, by the need for documentation and technical records; Dependency, by requiring interaction with other knowledge or professionals; and Utilization, by converting information and skills into effective and functional results.

4.8. Typology of Nordlöf, Hallström, and Hösts (2022) and Associated Characteristics

In Nordlöf, Hallström, and Höst's (2022) typology, technical skills are related to Observability, as they are identifiable in the execution of tasks; Usability, by their application in problem-solving; Complexity, by involving practical knowledge and adaptation to different contexts; and are difficult to codify, as they are, in part, tacit and acquired through practical experience. Scientific-technological knowledge is linked to normativity, by meeting scientific and technological criteria and standards; to Complexity, by the integration of theories, methods, and multidisciplinary analyses; and to descriptivity, by detailing phenomena and properties of technological systems based on scientific principles. Socioethical technical understanding is associated with Transmissibility, by being able to be communicated and debated in different contexts; to Codification, by being recorded in standards and guidelines; to Dependence, by the need for interdisciplinary dialogue between technicians, scientists, managers, and society; and Usability, for supporting decisions that balance technical feasibility and social responsibility.

4.9. Typology of Staddon (2022)

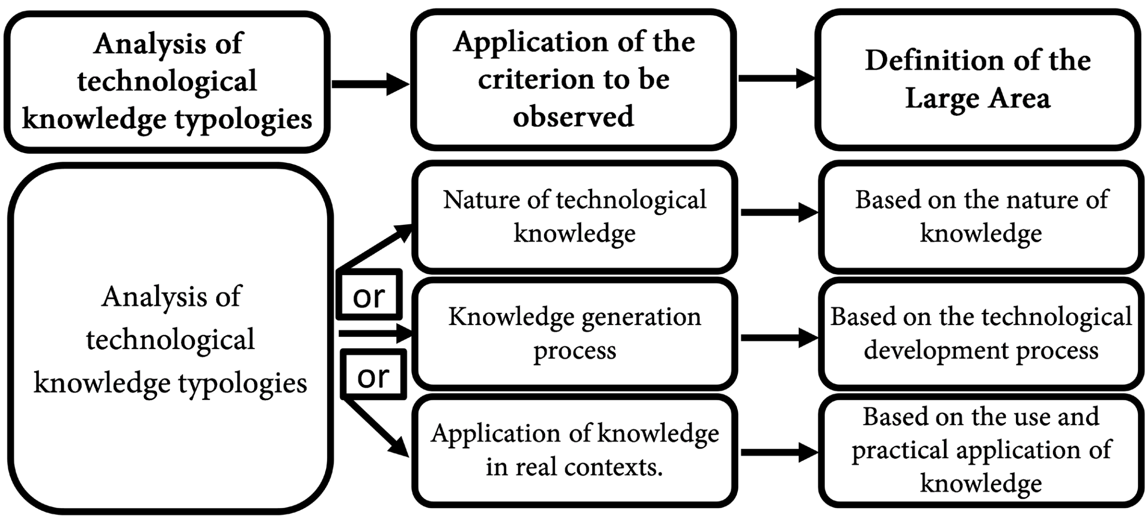
In Staddon's (2022) typology, practical knowledge is observable, for being manifested in the execution of tasks and the performance of concrete activities, and dependent, for requiring interaction with other knowledge and collaborative practices. Structural knowledge is associated with Observability, for analyzing operations and behavior; Complexity, for the high number of variables and interdependencies; Dependence, for requiring integration with other knowledge; Normativity, for following technical standards and performance requirements; and Descriptivity, for detailing the elements and relationships that support the analyzed structure. Computer science, on the other hand, is related to Prescriptivity, for proposing methods and instructions for creating or optimizing technologies; Normativity, for following standards and best practices; Complexity, due to the diversity of languages, architectures, and processes; Transmissibility, for being teachable; to codification, when recorded in formal codes and specifications; and to usability, through direct application in the development and implementation of technological solutions.

In this context, it is possible to note that the most recent typologies (Runyan, 2019; Nordlöf, Hallström, & Höst, 2022; Staddon, 2022) present nine characteristics of technological knowledge in an attempt to capture the broadest possible range for its characterization.

5. Analysis of Results

The literature review identified different approaches to classifying technological knowledge, which can be grouped into three broad areas: 1) typologies based on the nature of knowledge, 2) typologies based on the technological development process, and 3) typologies based on use and practical application. This synthesis derives from the analysis of the types proposed by each author and the dimensions emphasized in their classifications, highlighting when the focus falls on what knowledge is (ontology), how it is generated and linked in the project (process), or how it is executed and perceived in real-world contexts (use/application).

Based on these criteria, the typologies were examined and classified into a primary area (Figure 2).



Source: Authors.

Figure 2. Process of defining the major areas of technological knowledge typologies.

Typologies based on the nature of knowledge classify technological knowledge, focusing on its form, content, and mode of existence, before any other observation about this type of knowledge. Table 5 presents the typologies predominantly in these areas.

Table 5. Typology based on the nature of knowledge.

Author(s)	Typology	Rationale for classification
Vincenti (1984)	Descriptive; Prescriptive; Tacit	Defines knowledge ontologies.
Ropohl (1997)	Technological laws; Functional rules; Structural rules; Know-how	Classifies intrinsic forms of technological knowledge as generalizations, rules, and know-how.
de Vries (2003)	Physical nature; Functional nature; Means-ends; Action	When considering the physical and functional constitution of the artifact, it is linked to the ontology of technological knowledge.
Hansson (2013)	Tacit; Practical rules; Technological science; Applied natural science	Structures the types of knowledge aimed at technological education, with an ontological focus.

Typologies based on the technology development process are classifications related to the stages of technology creation, diffusion, and application. They describe project achievements, mapping knowledge categories that enable the design, specification, testing, and iteration of artifacts. The typologies that focus on this area are presented in Table 6.

Table 6. Typologies that make up the technological development process area.

Author(s)	Types of typology	Rationale for classification
Vincenti (1990)	Fundamental design concepts; Criteria/Specifications; Theoretical tools; Quantitative data; Practical considerations; Design tools	Organizes the development pipeline of an artifact, considering input, process, and output.
Runyan (2019)	Design modules; Knowledge creation; Use	Structures the project flow from creation to use, emphasizing how knowledge is chained and transformed.

Finally, the broad area involving typologies based on use and practical application highlights categories focused on the social, educational, or productive function of technologies, addressing how knowledge is implemented, appropriated, and viewed by users, educators, and society. Table 7 demonstrates the typologies that fall within this area.

Table 7. Typologies that make up the areas based on use and practical application.

Author(s)	Types of typology	Rationale for classification
Ihde (1997)	Knowledge through technologies (instrumental practice)	Emphasis on knowledge that emerges from the use and experience with instruments and technologies.
Nordlöf, Hallström, and Höst (2022)	Technical skills; Scientific-technological knowledge; Technical-socioethical understanding	Focus on execution, training, and implications of application in real-world contexts.
Staddon (2022)	Practical; Structural; in computer science	User and learner perspectives and understanding of knowledge operationalization.

It should be noted that Tables 5-7 summarize the primary classification of the typologies, defined based on the criteria of nature of knowledge, technological development process, and practical use and application. However, a comparative reading of the typologies highlights possible secondary classifications (**Table 8**) within the same macro-areas, which function as markers of transversality and do not imply a primary reclassification.

Table 8. Secondary classifications of typologies by broad area.

Broad area (primary classification)	Author(s)	Types of typology	Broad area—Rationale for classification (secondary)
Nature of knowledge	Vincenti (1984)	Descriptive; Prescriptive; Tacit	Process: Through the ontological distinction, it fosters learning by doing and the transfer of tacit knowledge throughout the ordered stages of the project.
	Ropohl (1997)	Technological laws; Functional rules; Structural rules; Know-how; Sociotechnological understanding	Process: Rules are considered "rules for engineering decisions". Use: Sociotechnological understanding connects to societal impacts and acceptability.
	de Vries (2003)	Physical nature; Functional nature; Means-ends; Action	Process: Means-ends and action operate as a link for how to operate, design, and measure maturity.
	Hansson (2013)	Tacit; Practical rules; Technological science; Applied natural science	Use: Educational focus considering execution and training, and the Transmissibility and Usability of knowledge.
Technological development process	Vincenti (1990)	Design concepts; Criteria and Specifications; Theoretical tools; Data; Practical considerations; Design instruments	Nature: By considering types of knowledge that arise from data and practices. Use: from testing and validation, observable evidence is generated, whether through pilots or trials.
	Runyan (2019)	Design; Knowledge Creation; Use	Use: The use module explains appropriation and allows for the derivation of metrics referring to practical application.
Use and practical application	Ihde (1997)	Knowledge through technologies (instrumental practice)	Nature: Discussion of ways of knowing that can generate ontological assumptions.
	Nordlöf, Hallström, and Höst (2022)	Technical skills; Scientific-technological knowledge; Technical-socioethical understanding	Nature: Evidence of types of knowledge mobilized. Process: Formative sequences and routines function as processes.
	Staddon (2022)	Practical; Structural; Computer science	Nature: Distinguishes ontological layers observed in practice and use.

Allocation of each typology to a single major primary area ensures analytical clarity and comparability among authors; in turn, secondary classifications clarify the possible real intersections between ontology, development, and application. This hybrid design connects the cognitive raw material (nature), the artifacts and routines that transform it (process), and the observable results that legitimize its adoption (use). Thus, theoretical coherence is preserved while still considering the practical utility of technological knowledge typologies, ensuring that they are both theoretically sound and empirically measurable.

It is worth noting that the characteristics of technological knowledge identified in the typologies (Table 4) function as indicators of classification within the three macro-areas (Tables 5-7). Generally speaking, the characteristics of codification, descriptivy, prescriptivy, and transmissibility tend to signal the nature of knowledge; Normativity, Complexity, and Dependence typically indicate the development process, while Observability and Usability refer to Use and application, allowing for the assessment of adoption and legitimacy in real-world contexts.

The results obtained demonstrate that the concept of technological knowledge remains in constant evolution, reflecting the transformations in the scientific and technological paradigms themselves. While classical studies tend to prioritize a technical and instrumental perspective, recent research broadens the scope to consider social and cognitive aspects. This theoretical diversity, while enriching, can compromise the construction of a conceptual consensus, which directly impacts the management and sharing of knowledge in organizations and academic settings. The lack of a widely accepted classification hinders comparability between studies and limits the formulation of science-driven public policies.

On the other hand, the plurality of approaches opens up space for interdisciplinarity, allowing different fields—such as engineering, information science, management, and education—to contribute to the refinement of the concept.

6. Contributions of Technological Knowledge

The proposed research, which organizes technological knowledge into three major areas—nature, development process, and practical application—can contribute to both organizational management and the formulation of technology policies.

For example, in organizational contexts, mapping technological knowledge according to these areas can improve the sharing of knowledge that is more appropriate for innovation management. Furthermore, by identifying whether the critical knowledge of a project is primarily ontological (nature), procedural (development process), or operational (use and application), managers can select appropriate mechanisms for its codification and dissemination.

In research and development departments, for example, this facilitates the design of knowledge repositories and learning routines aligned with the specific characteristics of the knowledge involved—whether it be the need for documentation standards, collaborative prototyping, or user feedback loops.

In the context of policy formulation, the research assists in structuring technology and innovation policies that differentiate between the stages of knowledge generation and use. For example, policies supporting universities and technology transfer offices can focus on strengthening knowledge in the area of the development process, such as the design and validation of prototypes, while industrial and social innovation programs can target knowledge in the area of use and application, promoting the diffusion and adaptation of technologies across regions and sectors.

By providing this classification, the model allows decision-makers to align incentives, metrics, and funding mechanisms with the specific characteristics of technological knowledge, reducing the conceptual ambiguity that currently limits comparability between initiatives and effective integration between science, technology, and innovation systems.

In summary, by structuring technological knowledge into three broad areas, this study demonstrates that a clearer understanding of each dimension can enhance knowledge sharing and underpin technological policies. Recognizing the nature of knowledge allows organizations to identify what should be codified or shared; analyzing the development process supports the creation of collaboration and learning mechanisms during innovation; and focusing on practical application facilitates the dissemination and adaptation of knowledge in real-world contexts. However, the lack of consensus on typologies of technological knowledge continues to limit the formulation of coherent policies and the effective management of knowledge within organizations.

Without a common understanding or standardized typology of technological knowledge, organizations and policymakers lack clear criteria to identify, measure, and manage what kind of knowledge they are dealing with. This ambiguity hinders comparability between projects and sectors, makes it difficult to design policies aligned with real knowledge needs, and limits the creation of strategies for sharing and transferring knowledge effectively. The absence of consensus prevents coherent decisions about how to support, regulate, and disseminate technological knowledge in both organizational and policy contexts.

7. Final Considerations

This article presented a systematized review of the types of technological knowledge described in the literature, identifying convergences and divergences among different authors and classifications. The results reveal a wide conceptual diversity regarding what constitutes technological knowledge and how it should be categorized (Vincenti, 1990; Ropohl, 1997; de Vries, 2003; Hansson, 2013; Runyan, 2019; Nordlöf, Hallström, & Höst, 2022; Staddon, 2022). While this plurality enriches the theoretical debate, it also produces a conceptual fragmentation that hinders the accumulation of comparable results and limits the formulation of coherent innovation and knowledge management policies.

To address this fragmentation, this study proposed an integrative structure that organizes technological knowledge into three broad areas: 1) the nature of knowledge, 2) the technological development process, and 3) its use and practical application. These three areas systematize dispersed contributions, clarifies relationships between typologies, and allows for a progressive understanding of how technological knowledge is conceived, generated, and applied. By establishing these analytical boundaries, the research helps overcome terminological ambiguities and supports the development of cumulative research capable of comparing typologies under shared criteria.

From a practical standpoint, the structure also provides a foundation for improving knowledge sharing within organizations and for informing technology and innovation policies. Understanding the nature of technological knowledge helps identify which elements can be codified or shared; examining the development process highlights opportunities for collaboration and learning during project execution; and focusing on practical application facilitates the transfer, adaptation, and social appropriation of knowledge in real contexts. Thus, the model contributes to more coherent decision-making, linking theoretical understanding with managerial and policy relevance.

Nevertheless, the lack of consensus on technological knowledge typologies continues to limit the formulation of consistent policies and the effective management of knowledge within organizations. Without common characteristics, it remains difficult to define indicators, measure knowledge transfer, or design governance mechanisms aligned with the real dynamics of knowledge creation and use. The proposed research mitigates these limitations by offering a shared reference that integrates cognitive, procedural, and applicative dimensions, thereby aligning theoretical coherence with practical usability.

In summary, this study contributes to the field by systematizing dispersed typologies, identifying conceptual gaps that limit practical application, and proposing an integrative theoretical basis to guide future empirical studies on technological knowledge sharing. It is recommended that subsequent research test this classification in organizational and institutional contexts to validate its applicability and refine its indicators.

Limitations include the restriction to three databases and the exclusion of non-indexed publications, which may have reduced the scope of the review. For future research, we recommend expanding the corpus of analysis and applying the proposed model empirically in diverse sectors to assess its potential for consolidating the understanding and management of technological knowledge.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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