Journal of International Education and Development
2025, VOL. 9, NO. 1, 32-35
DOI: 10.47297/wspiedWSP2516-250006.20250901

Constructing a Framework for the Classification of Technological Knowledge in STEM Education

Yi Pan, Yuli Dong

College of Physics and Technology, Soochow University, Suzhou, Jiangsu, 215006, China

ABSTRACT
Technological education is a critical component of STEM education, and technological knowledge forms the essential foundation for project-based learning and interdisciplinary practice. However, there is a significant gap in teachers' understanding of technological knowledge in STEM disciplines, leading to a lack of necessary knowledge when students engage in practical activities. To address this issue, this study deconstructs the internal structure of technological knowledge based on philosophical discussions of technology. First, using modular theory, technological knowledge is divided into three modules: design knowledge, transformation or production knowledge, and operation and usage knowledge. Second, considering the iterative relationships between technological artifacts, a relational model is established to describe the interactions among technological knowledge modules at different levels of artifacts. Finally, this framework integrates the philosophical perspectives on the classification of technological knowledge.

KEYWORDS
STEM education; technological education; technological knowledge; knowledge classification

1 Introduction

With the rapid advancement of global science and technology, a highly skilled workforce in science, technology, engineering, and mathematics (STEM) is crucial for national competitiveness[1]. Therefore, STEM education in primary and secondary schools has received increasing attention in China. However, compared to science, mathematics, and engineering, technological education in Chinese schools has garnered less attention, and its implementation faces significant challenges. One of the key issues hindering the effective implementation of STEM education is the insufficient development of technological knowledge among STEM teachers and their lack of technological literacy[2], which has become one of the major obstacles to the high-quality implementation of STEM education[3].

Knowledge is the foundation of thought[4], and the core component of education. It plays a crucial role in curriculum structure, teaching practices, and student learning. From an epistemological perspective, understanding the connotation of technological knowledge and clarifying its internal structure are key to successfully conducting project-based learning and interdisciplinary practice. Therefore, this study, based on relevant research in the philosophy of technology and modular theory, constructs a framework for classifying technological knowledge around the design, production, and use of technological artifacts, providing valuable reference for the development of STEM education.

2 Classification of Technological Knowledge Modules Based on Modularity Theory

To investigate the technological knowledge in STEM curricula, it is necessary to first address the fundamental question of what technological knowledge is. Only then can we filter out technological knowledge from the vast array of knowledge and information. Davis argues that technological knowledge is embedded in the processes of designing, making, and using technological artifacts, and that it is also a crucial component of technological education. Therefore, exploring the design, production, and use processes of technological artifacts is one of the main tasks of technological education. The core content of technological education is to help students develop a profound understanding of the essence of artifacts through the analysis of their "structure" and "function." By engaging in structured activities such as "investigating, dismantling, assembling, connecting, and evaluating simple products," students gradually build a mental model of the structure-function relationship of artifacts. This model facilitates the transition to more open-ended learning activities such as "designing and producing finished products." The teaching process of technological education can thus be summarized into three module stages: the design knowledge stage, the modification or production knowledge stage, and the usage knowledge stage.

Modularity Theory, proposed in 1997 by C. Baldwin and K. Clark of Harvard University in their paper Managing in the Age of Modularity, refers to the ability of system components to be separated and reassembled. In technological practice, the application of modularity has expanded beyond traditional industries such as automotive manufacturing and has increasingly been applied to the design process of technological artifacts. The fundamental premise of modularity theory is that objects have both decomposability and integrability, making these characteristics essential for the modular classification of technological knowledge. In reality, the structure of technological artifacts dynamically evolves from integration to modularization and back to integration. Based on this, it can be inferred that the process of designing, modifying, and producing technological artifacts is also a process of modularizing technological knowledge.

Based on the above theory of modularity and the three-stage changes in the teaching process of technological education, technological knowledge can be decomposed into three modules: design knowledge, modification or production knowledge, and operation and usage knowledge. This classification aligns with the perspectives of scholars such as Lin Runyan and Wu Guolin, who, after reviewing the viewpoints of foreign scholars like Carpenter[5], Mitcham[6], Vincenti[7], Faulkner[8], Roboh[9], and Davis[10], proposed similar classifications. Among these, the design knowledge module can be further divided into external functional knowledge and internal structural knowledge in subsequent discussions.

3 Establishing the Relationships Among Technological Knowledge Modules Based on the Iterativity of Technological Artifacts

Although the technological knowledge framework based on modularity theory provides new insights, it still has limitations. One major issue is that if different technological artifacts are considered, the same technological activity may correspond to different technological behavior modules, leading to confusion in the classification of technological knowledge. For example, during the process of making a fan, the technological knowledge involved could be classified under the modification and production module of the fan, or it could correspond to the operation and usage modules of components such as capacitors and motors. In this case, it becomes unclear to which module the "technical know-how" belongs. This issue can be explained by the iterativity of technological artifacts, as described by Richard Grandy, which means that technological artifacts are generated by other artifacts and typically require multiple iterations to be created[11]. As in the example above, the fan, as a technological artifact, is made up of lower-level technological artifacts such as capacitors and motors, and it can also be used as a cooling tool in higher-level technological artifacts such as computer cases or projectors. Therefore, to create a more logically coherent framework for analyzing technological knowledge, it is necessary to highlight the technological artifacts referred to by each technological behavior module. This also implies the need to clarify the relationships between different technological artifacts. Based on this analysis, this study reorganizes the relationships among technological knowledge modules from a top-down perspective, considering the iterative nature of technological artifacts, as shown in Figure 1.

The framework shown in Figure 1 first presents the four categories of technological knowledge modules corresponding to each technological artifact, as well as the internal connections between these modules. Technological

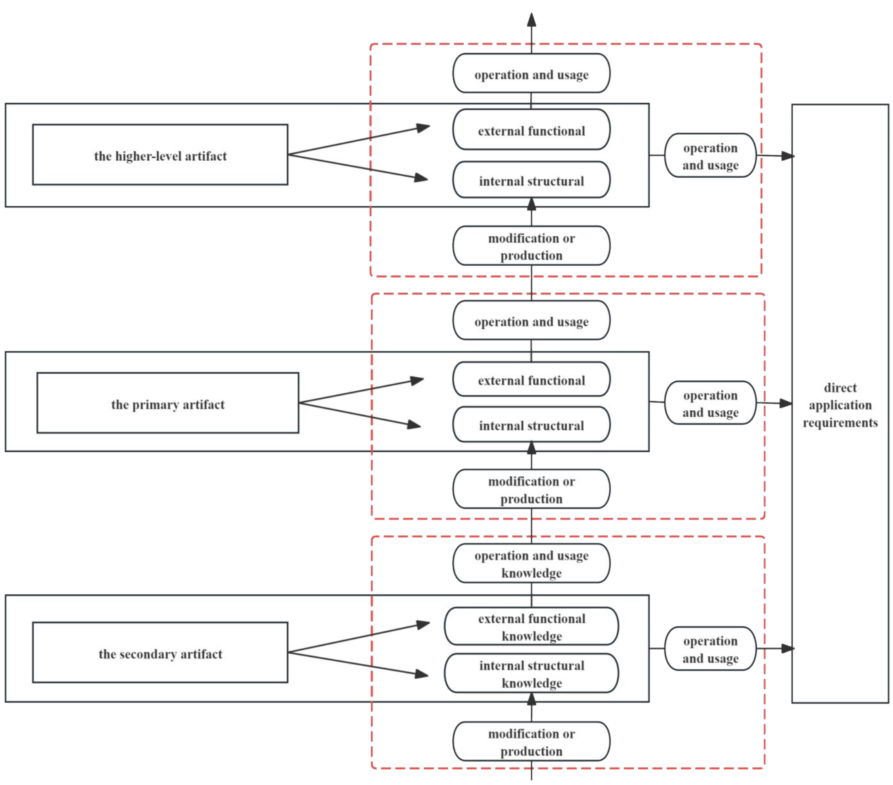

Figure 1 Framework of the Relationships Among Technological Knowledge Modules

knowledge modules can be mainly divided into four parts: external functional knowledge, internal structural knowledge, modification or production knowledge, and operation and usage knowledge. Among these, "internal structural knowledge" and "external functional knowledge" refer to the intrinsic properties of each technological artifact. They represent two dimensions through which we understand technological artifacts, corresponding to Cross and Meyers' definition of the dual nature of technological artifacts[12]. Around this dual nature, humans engage in the "modification or production" and "operation and usage" of technological artifacts. "Modification or production" is based on "internal structure," while "operation and usage" is based on "external function." Thus, the internal connections among the four types of technological knowledge modules are established.

Furthermore, the framework illustrates the external relationships of technological knowledge modules across different levels of technological artifacts. Each technological artifact does not exist in isolation; the essence of "iteration" lies in the way the "external functional knowledge" of a secondary technological artifact is determined by and selects the "internal structural knowledge" of the higher-level artifact, thus linking technological artifacts of different levels. This linking process represents the interaction between "operation and usage knowledge" of a secondary technological artifact and "modification or production knowledge" of a higher-level technological artifact. Both processes occur simultaneously within the same technological activity, but they focus on different technological artifacts.

4 Classification of Technological Knowledge Based on Technological Knowledge Modules

Based on the aforementioned classification of technological knowledge modules, it can be observed that the three categories of technological knowledge align with and encompass the refined classifications proposed by various technology philosophers, such as Vincenti[13], Roboh[14], and Davis[15]. In the context of Chinese science textbooks, these categories can be specifically summarized as follows: internal structure knowledge within design knowledge includes structural composition, structure-function, and material knowledge; external functional knowledge within design knowledge includes functional knowledge, purpose knowledge, and socio-technical knowledge; modification or production knowledge includes production rules, means-ends knowledge, and process data; operation and usage knowledge includes usage rules, technological principles, and technical tricks. Ultimately, the study synthesizes and organizes these into the classification table of technological knowledge, as presented in Table 1.

Table 1 Classification of Technological Knowledge

Design Knowledge		Modification or Production Knowledge	Operation and Usage Knowledge
Internal Structural Knowledge	External Functional Knowledge		
Structural Composition	Functional Knowledge	Production Rules	Usage rules
Structure-Function	Purpose Knowledge	Means-Ends Knowledge	Technological principles
Material Knowledge	Socio-Technical Knowledge	Process Data	Technical tricks

5 Conclusion

Based on the modularity theory and the three-stage changes in the technological education process, technological knowledge can be decomposed into three modules: design knowledge, modification or production knowledge, and operation and usage knowledge. Among these, the design knowledge module can be further divided into internal structural knowledge and external functional knowledge. When applying these knowledge modules, it is important to consider the technological artifacts they correspond to, in order to avoid confusion caused by the iterativity of technological artifacts. Finally, this technological knowledge framework integrates the discussions of philosophers of technology on the classification of technological knowledge, providing a epistemological reference for the implementation of technological education within STEM education.

References

[1] Chinese National Institute of Education Sciences. (2018). China STEM Education White Paper (Report No. 2018-05-07). National Center for STEM Education, Institute of Education Sciences.

[2] Kang Q. (2015). The current situation of technological education in China and suggestions for introducing the "Design and Technology" curriculum at the primary school level. Journal of Beijing Normal University (Natural Science Edition), 10(3), 52-56.

[3] Dong Y., Wu N., & Xia L. (2024). STEM education teacher development and new quality enhancement from the perspective of organization and human resources. Journal of Guangxi Normal University (Philosophy and Social Sciences Edition), 60(5), 66-75.

[4] Bai Q., Feng Y., Shen S., et al. (2020). Re-recognition and re-evaluation: Piaget's constructivism and its learning theory in his perspective. Journal of East China Normal University (Education Science Edition), 38(3), 106-116.

[5] Carpenter S. R. (1974). Modes of knowing and technological action. Philosophy Today, 18(2), 162-168.

[6] Mitcham C. (1978). Types of technology. Research in Philosophy and Technology, 1(1), 229-294.

[7] Vincenti W. (1990). What engineers know and how they know it: Analytical studies from aeronautical history. Johns Hopkins University Press.

[8] Faulkner W. (1994). Conceptualizing knowledge used in innovation. Science, Technology & Human Values, 19(4), 425-458.

[9] Ropohl G. (1997). Knowledge types in technology. International Journal of Technology and Design Education, 7, 65-72.

[10] De Vries M. J. (2005). The nature of technological knowledge: Philosophical reflections and educational consequences. International Journal of Technology and Design Education, 15, 149-154.

[11] Grandy R. E. (2007). Artifacts: Parts and principles. In E. Margolis & S. Laurence (Eds.), Creations of the mind: Theories of artifacts and their representation (pp. 18-32). Oxford University Press.

[12] Hansson S. O. (2002). Understanding technological function: Introduction to the special issue on the dual nature programme. Techné, 6(2), 87-92.

[13] Vincenti W. (1990). What engineers know and how they know it: Analytical studies from aeronautical history. Johns Hopkins University Press.

[14] Ropohl G. (1997). Knowledge types in technology. International Journal of Technology and Design Education, 7, 65-72.

[15] De Vries M. J. (2005). The nature of technological knowledge: Philosophical reflections and educational consequences. International Journal of Technology and Design Education, 15, 149-154.