

Construction and Practice of the PBL Model for Cultivating Core Information Technology Literacy in Junior High School Students from the Perspective of Embodied Cognition—Taking "Smart Eco-Box: IoT Data Collection and Remote Control" as an Example

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Abstract: Addressing the current phenomenon of 'separation of mind and body' in junior high school information technology education, which refers to the disconnection between knowledge transmission and physical experience as well as situational perception, guided by embodied cognition theory and implemented through project-based learning, this study integrates the three core characteristics of embodied cognition into six instructional processes of project-based learning. By constructing a project-based learning model from an embodied cognition perspective, it aims to achieve holistic physical and mental integration in teaching practices. Building upon KUDB, we innovatively proposed the E-KUDB teaching objective model. This framework enables educators to establish learning goals by emphasizing that knowledge acquisition, comprehension, skill development, and competency attainment must follow embodied pathways including bodily perception, experiential engagement, and reflective internalization. The ultimate validation of students' core competencies is achieved through systematic assessment of goal fulfillment. The final practical application through the information technology teaching case "Smart Eco-Box: IoT Data Collection and Remote Control" demonstrated that this model effectively facilitates students' deep cognitive development through multisensory engagement, hands-on practice, and real-world scenarios. It achieves an organic integration of "doing, thinking, speaking, and acting" to enhance students' core competencies. The study provides theoretical support and practical.

Keywords: embodied cognition; project-based learning; information technology; core competencies; E-KUDB model

1. Introduction

The "Compulsory Education Information Technology Curriculum Standards (2022 Edition)" emphasizes the use of real-world problems or project-based approaches to help students construct knowledge, enhance their engagement, and focus on creating authentic scenarios. This methodology enables students to learn through doing, applying knowledge, and innovating, thereby fostering their core competencies. However, current junior high school information technology teaching practices exhibit a phenomenon of disconnection—knowledge transmission often remains confined to mechanical memorization of abstract symbols and operational steps, while students' physical experiences, situational awareness, and cognitive processes are artificially severed from organic integration. This traditional "teacher demonstration-student imitation" model often results in vague cultivation of core competencies, lacking specificity and overlooking the critical role of the "body" in cognitive construction. Students merely engage their brains during lectures without physical experience, making it difficult to truly internalize knowledge as competencies. Building on this foundation, this study employs embodied cognition theory and project-based learning as a practical approach to explore instructional design models for cultivating core information technology literacy among junior high school students^[1], aiming to provide innovative insights for information technology curriculum teaching in basic education from both theoretical and practical perspectives. Embodied cognition theory emphasizes that cognition is rooted in the interaction between the body and the environment, advocating the construction of knowledge meaning through bodily perception, action experience, and situational interaction. This

provides a crucial theoretical perspective for addressing the challenge of "mind-body disconnection" in information technology education. Project-based learning is driven by real-world problems, centered on practical inquiry, and outcome-oriented, achieving an organic integration of "doing, thinking, speaking, and acting" at the practical level.

2. Ontological Adaptation of Embodied Cognitive Theory in Information Technology Education

Embodied cognition theory emphasizes that the body is integrated into the environment and acts on cognitive processes. In recent years, this view has become a hot topic in learning science research. Chen Xingye and Li Man leveraged the disciplinary characteristics of information technology—'perception-abstraction-computation'—to integrate embodied cognition into information technology courses. They developed embodied learning frameworks, designed and implemented embodied activities, which significantly enhanced students' learning interest and classroom engagement, effectively improved learning outcomes, and promoted metacognitive development^[2]Wang Meiqian and colleagues applied embodied cognition to information technology, utilizing embodied information practices to foster the substantive development of information literacy, enhance individuals' capacity to cope with technological alienation, and achieve students' autonomous, comprehensive, and personalized growth^[3]. Xu Xueying introduced embodied cognition to address the issues of overemphasis on operational skills and neglect of principles in junior high school information technology education, as well as the disconnection between theoretical instruction and practical application. This approach aligns with the curriculum standards' requirement for equal emphasis on scientific knowledge and technical skills, thereby fostering students' core competencies^[4].Zhao Xue and colleagues introduced embodied cognition to develop tailored training frameworks and practical models, offering innovative approaches for cultivating digital literacy in primary school information technology education^[5].It effectively cultivates students' digital literacy such as digital awareness and computational thinking. It is evident that the ontological adaptation of embodied cognition theory in information technology education has demonstrated distinct local adaptability through multi-stage and multi-themed practices.

3. Analysis of Compatibility between Embodied Cognition and Project-Based Learning

Embodied cognition theory emphasizes the inseparability of body and cognition, advocating the concept of "mind-body unity" or "mind-body monism"^[6].Project-based learning is a comprehensive teaching, learning, and curriculum model that is grounded in real-world contexts, student-centered, and problem-oriented^[7]. It aims to guide students in learning by doing. Although they originate from different theories, they exhibit certain intrinsic compatibility. In terms of objectives, both approaches address the dichotomy between mind and body in traditional education, facilitating a shift from symbolic processing to holistic mind-body integration that fosters deep knowledge construction and core competency development. Regarding value functions, embodied cognition provides theoretical foundations for project-based learning by highlighting the pivotal role of bodily experience in cognitive development, while project-based learning serves as a practical vehicle for embodied cognition, transforming abstract theories into actionable teaching models that bridge theory and practice. In core elements, both emphasize that knowledge acquisition should transcend passive instruction, requiring hands-on engagement and physical participation within authentic, perceptible contexts. Only through such immersive environments do bodily perceptions gain significance, investigative activities acquire direction, and cognitive understanding achieve profound depth. Based on this, embodied cognition and project-based learning demonstrate a certain degree of compatibility. The organic integration of these two approaches provides theoretical support and practical pathways for addressing current challenges in education, such as the separation of physical and mental development and suboptimal outcomes in core competency cultivation.

4. Project-Based Learning Model from the Perspective of Embodied Cognition

4.1 Construction of Project-Based Learning Model from the Perspective of Embodied Cognition

Develop a project-based learning model grounded in the perspective of embodied cognition to better cultivate students' core competencies (see Figure 1).Embodied cognition theory posits that cognition is grounded in experiences generated by various bodily senses. When the body integrates into different physical, physiological, and cultural environments, new cognitions emerge through the adaptation of

the body and its modes of activity to the environment^{[8][9]}. As a cognitive theory arising from the interaction between the body and the external environment, embodied cognition theory is characterized by three key features: embodiedness, situationality, and experientiality^[10]. Immersiveness requires the full utilization of students' physical sensory systems during the teaching process, including organs such as eyes, ears, hands, and brain, to ensure that classroom knowledge can effectively enter students' cognitive domains through multidimensional pathways. Ultimately, students construct a more comprehensive and accurate knowledge system through integrated information processing by the brain^[11]. Contextualization emphasizes the creation and utilization of teaching environments, which include indoor teaching environments, outdoor teaching environments, and virtual teaching environments. The creation of authentic teaching scenarios stimulates students' physical engagement, enabling them to learn in real-world contexts and thereby improving learning effectiveness. Experiential learning permeates the entire project-based learning process, where students engage in hands-on operations and physical construction, maintaining continuous interaction between their bodies and the environment. This approach achieves the integration of "doing, thinking, speaking, and acting" during the learning experience.

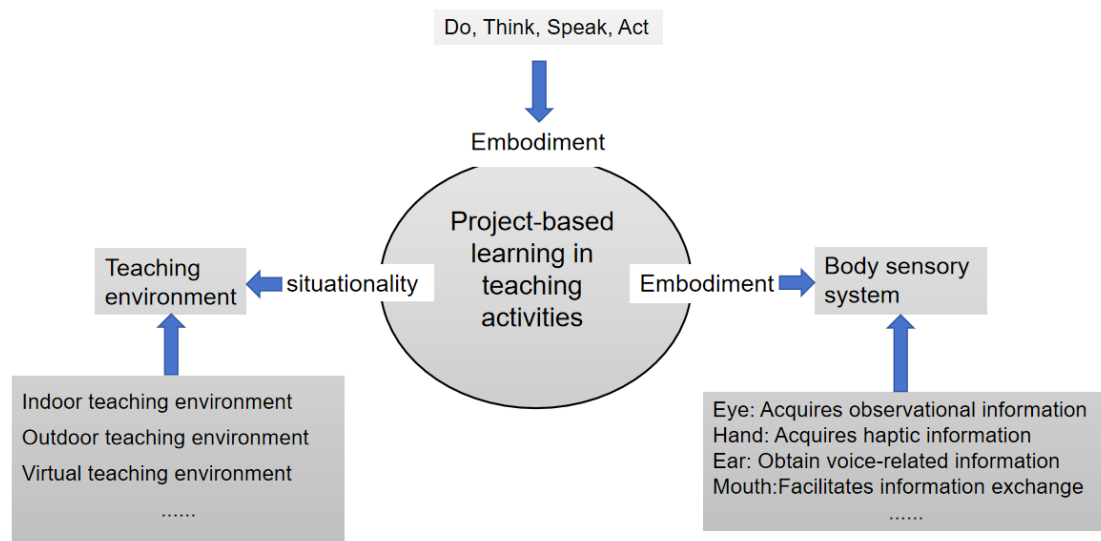


Figure 1 Project-based Learning Model from the Perspective of Embodied Cognition

4.2 Process of Conducting Teaching Activities

Integrating embodied cognition into project-based learning, constructing a project-based learning process from the perspective of embodied cognition, and applying it to junior high school information technology courses to cultivate students' core competencies (as shown in Figure 2). The research divides the project-based learning process into 6 stages: ① Confirm the theme and clarify the task. Teachers create embodied problem scenarios, design multi-sensory entry activities, and allow students to engage in physical perception and situational experience during learning, obtaining first-hand experiential knowledge, transforming external problems into personal feelings. ② Clarify the goals. Teachers formulate teaching goals that involve physical participation throughout the process and focus on the implementation of practical results; students conduct action-oriented and role-playing, establishing a deep connection between the body and the task, strengthening the sense of participation and immersion in learning. ③ Task decomposition. Teachers break down the tasks into exploratory sub-tasks that emphasize physical participation based on the project goals. Students engage in physical participation, understanding, and implementing these sub-tasks to achieve deep learning through doing and practicing. ④ Project implementation. Teachers guide embodied project creation, pay attention to the students' implementation process, and provide "hands-on" guidance when necessary, rather than directly giving answers. Students operate and construct by hand, converting abstract knowledge into specific results, strengthening their practical thinking ability. ⑤ Project evaluation. Teachers organize embodied project exhibition and evaluation, taking into account both the report and practice of the work, with a focus on physical presentation, practical demonstration, and on-site responses. Students present their works through physical expression and physical display, thinking and obtaining multi-dimensional evaluation information from the body feedback, and discovering the strengths and weaknesses of the work. ⑥ Reflection and summary. Teachers guide students to go beyond textual summaries and conduct embodied

reflection. This prompts students to internalize practicality and make knowledge explicit, strengthening their transfer ability in complex future situations. At the same time, the teaching process integrates interdisciplinary thinking, from task decomposition, practical exploration to exhibition and reflection, guiding students to integrate multiple disciplinary knowledge to solve problems, complete creations, and deepen learning effectiveness through communication and sharing.

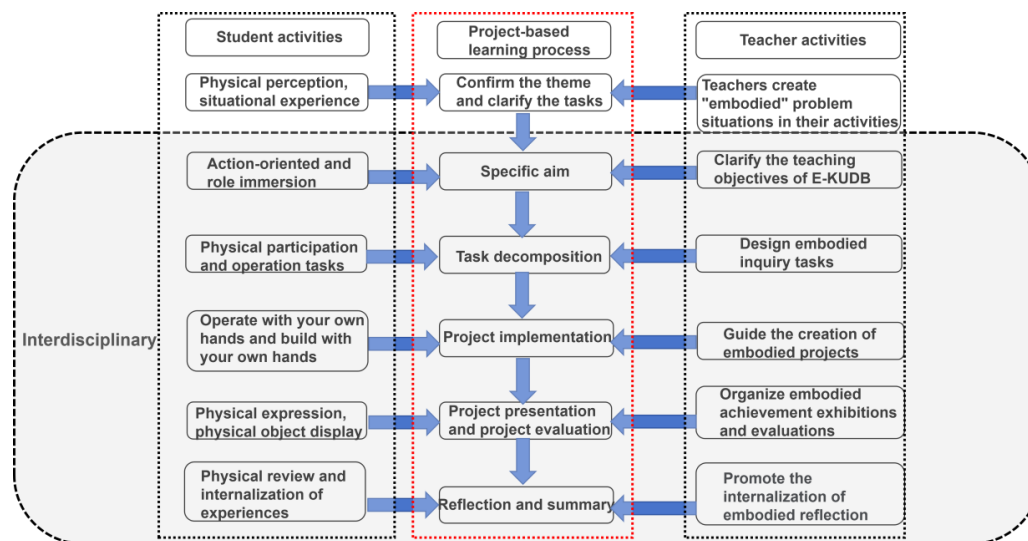


Figure 2: Project-based Learning Process from the Perspective of Embodied Cognition

4.3 Development of Teaching Objectives for E-KUDB

The KUD model was proposed by Erikson and Laning. Based on the KUD framework, Li Songlin^[12] focused on the requirements for cultivating core competencies and proposed the "Know-Understand-Do-Be" (KUDB) model, which means that students should know (K) what facts, understand (U) what principles, be able to do (D) what works, and ultimately become (B) a person with certain competencies^[13]. On the basis of KUDB, this study integrates embodied cognition into it and proposes the E-KUDB teaching objective model (as shown in Figure 3). Here, E stands for "embodiment", and the learner's body is regarded as the fundamental medium for cognitive generation, emphasizing that knowledge acquisition, meaning construction, skill formation, and attitude internalization all originate from the interaction between the body and the context. The teaching design should no longer consider "knowing, understanding, doing, and forming attitudes" as thinking activities detached from the body, but through physical and mental operations, transform abstract goals into perceptible, operable, and reflective bodily experiences, thereby achieving transferable learning effects. E is not the fifth objective; rather, it is the embodied expression of the first four objectives.

Know (Mastering Knowledge) emphasizes the acquisition of interdisciplinary and conceptual knowledge, suggesting that knowledge is not isolated and abstract symbols, but stems from the interactive experiences of the body in multi-disciplinary contexts. When students solve real problems, they integrate multiple disciplinary knowledge, perceive, understand, and internalize knowledge through interactions with specific objects and environments, forming a vivid and meaningful knowledge structure. E-Understand (Understanding Relationships and Structures) aims to go beyond mechanical memorization, guiding students to grasp the intrinsic connections and laws between knowledge through embodied activities such as role-playing and simulation scenarios, and constructing frameworks and developing innovative thinking, allowing students to experience and understand the complex interrelationships among elements in problem-solving, achieving learning by doing and learning through practice. E-Do (Problem-solving Skills) focuses on students' comprehensive ability to apply knowledge to solve problems in real situations, covering process methods, inquiry practices, and problem-solving, and implementing these through hands-on construction and prototype-making and other embodied practices. E-Be (Forming Attitudes and Responsibilities) is the highest level of teaching objectives, focusing on the cultivation of students' internal attitudes, social responsibilities, and ethical and moral values, and the internalization of core competencies depends on physical review and reflection. By using the E-KUDB model, specific, achievable, and embodied teaching goals can be designed, and the achievement of these goals can be evaluated to verify the development level of students' core competencies.

This model is an elaboration and reconfiguration of the traditional KUDB model. Compared with the traditional model, it has certain differences. Firstly, the traditional model regards the body merely as a carrier for knowledge transmission or an organ for skill execution, with cognition still centered on the brain. However, E-KUDB regards the body as the fundamental medium for cognitive generation. All goals must be achieved through perception, action and interaction with the context; Secondly, the traditional model presents a linear progressive relationship of $K \rightarrow U \rightarrow D \rightarrow B$. E-KUDB constructs a circular interpenetration relationship with the body as the bond. Knowledge, understanding, skills and attitudes are mutually generated in hands-on operations, context experiences and body reflections; Finally, the traditional model provides abstract statements of literacy goals, which are difficult to be directly evaluated. However, E-KUDB anchors the literacy into observable physical behavior indicators through embodied activities, forming a transformation from abstract goals to physical evidence chains, thus completely achieving the transformation from disembodied cognition to embodied cognition.

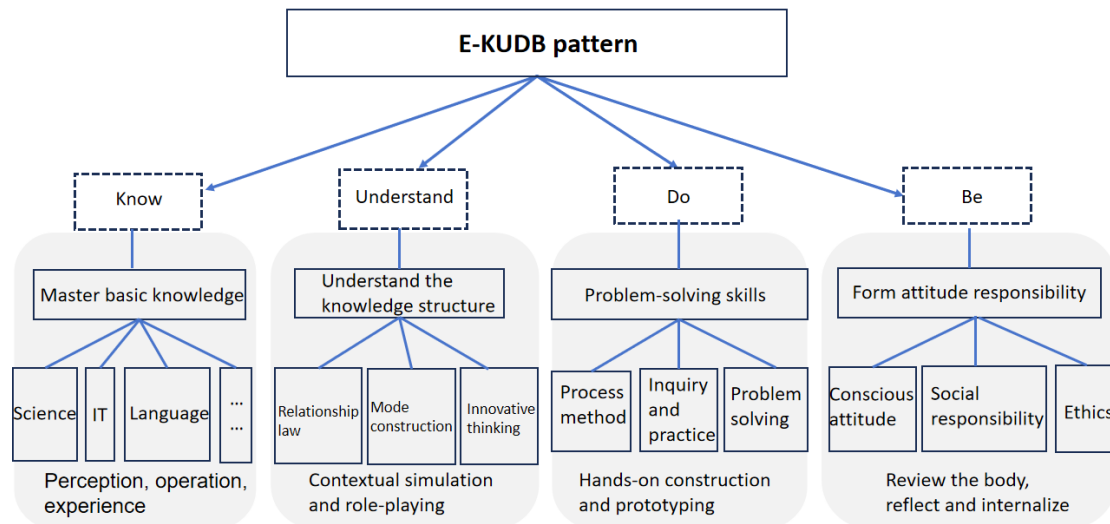


Figure 3 E-KUDB Model

5. Project-Based Learning in Information Technology for Junior High School Students from the Perspective of Embodied Cognition

This case study focuses on the "Internet of Things Module" in junior high school information technology, choosing "Smart Ecological Box" as the project theme and targeting seventh-grade students. The teaching is carried out through the methods of embodied cognition and project-based learning, allowing students to engage in embodied activities such as multi-sensory immersion, hands-on construction, physical expression, and physical review. Through these activities, students can achieve the integration of "doing, thinking, speaking, and acting" in the learning process, thereby effectively cultivating their core competencies.

5.1 Confirm the topic, clarify the task

The teacher does not simply present the "Wisdom Ecological Box" theme. Instead, they place a wilted green plant that has died due to improper watering in a corner of the classroom, guiding students to engage in multiple sensory experiences such as close observation, touching, and smelling. This enables students to shift from knowing that the plant has withered to experiencing the withering themselves, forming a profound first-hand experiential knowledge and empathetic concern. This embodied activity design allows students to truly perceive the existence of the problem through physical participation, and naturally leads to the learning topic.

5.2 Set clear goals

Based on the teaching content, teachers, following the E-KUDB model, formulate personalized teaching goals to ensure that the achievement of these goals runs through the entire process of students' physical participation. In the E-Know dimension, students can master the growth conditions of plants through multi-sensory participation, understand the working principle of the Internet of Things, data

analysis and threshold setting, and learn to write and summarize solutions. In the E-Understand dimension, students can understand the logical relationship of "data collection - transmission - processing - execution" through role-playing and hands-on operations; understand the correlation between sensor data and plant needs. In the E-Do dimension, students can build the IoT monitoring system through hands-on construction and programming; set thresholds to achieve automatic control; and connect to the IoT platform to achieve remote control. In the E-Be dimension, students can form a sense of responsibility for using technology to solve real problems through physical reflection and recall; and develop data privacy and ethical awareness. Through their actions, students establish a deep connection between their bodies and tasks, enhancing their sense of purpose and immersion in learning.

5.3 Task Decomposition

Based on the project goals, the teacher breaks down the overall task into four prominent experiential and exploratory sub-tasks. They are: Task 1: Perceive everything, understand sensors, control boards, and actuators, and complete hardware connections. Task 2: Data exploration, write programs to read sensor data, and understand the meaning of "collection". Task 3: Intelligent decision-making, set thresholds to achieve automatic control, and understand "judgment" and "execution". Task 4: Remote connection, connect to the Internet of Things platform, and achieve remote monitoring and control. Under the guidance of the teacher, students understand, take ownership of, and collaboratively plan the sub-tasks. Within the group, they cooperate and execute the tasks, and during the task execution, students achieve the organic unity of "doing, thinking, speaking, and acting" through physical participation.

5.4 Project Implementation

During the project implementation, teachers pay attention to the students' implementation process. When students encounter difficulties, they are given hands-on guidance. For instance, if the sensor has no data or the equipment malfunctions, the students are guided to manually check the circuits, touch and inspect the interface tightness, gently press the sensor to observe the data changes, allowing them to discover and solve the problems independently. Each group selects plants around the smart ecological box, operates and implements the construction of the Internet of Things monitoring system, programs and debugs, and uploads the data to the Internet of Things platform. They also consult relevant materials to determine the suitable temperature and humidity for the plants, and write a plan to explain the design ideas of the system.

5.5 Project Presentation Evaluation

The teacher organized an exhibition and evaluation of the "Body Present" project results, such as the Wisdom Ecological Box Expo. The evaluation was not only based on written reports, but also focused on physical displays, operational smoothness, and on-site response capabilities. Each group of students presented their Wisdom Ecological Box works in turn. Through physical operation demonstrations, the real-time operation effects of the equipment were presented intuitively; at the same time, body explanations, role-playing, etc. were used to vividly display ecological requirements. Students internalized the knowledge and presented it externally in an embodied manner through their own demonstrations. Questions raised by teachers and students during interaction, on-site feedback, as well as the highlights and shortcomings in the operation process, all became the basis for diverse evaluations.

5.6 Reflection and Summary

Teachers guide students to engage in embodied reflection. For instance, students can adopt fixed postures to re-create the unforgettable moments of the project, bend over to plug the wires to demonstrate their concentration during wiring, raise their hands to cheer to express the joy of successfully debugging the system; or use body movements to simulate the entire process of exploration from identifying problems to solving them throughout the inquiry. This enables the internalization of experiences, guiding students to reflect on ethical issues such as data privacy and the relationship between technology and people, and fostering a correct and responsible attitude towards the application of technology.

After the project is completed, based on the works, reports generated during the implementation, as well as the students' adaptability in class, participation level, etc., and relying on the achievement of the four-dimensional goals of E-KUDB in detecting the goals, the core literacy development of the students is evaluated, and the effectiveness of the project-based learning model from the perspective of embodied

cognition is verified. From the results, students have solidified their understanding of the concepts of the Internet of Things, technical principles, and knowledge of plant growth; deeply understood the system architecture and internal logic; have the practical ability to independently build and debug the Internet of Things system; and have established a sense of responsibility for using technology to solve real problems. The overall implementation effect is good, effectively confirming the positive role of this model in cultivating students' core literacy.

6. Research Conclusions and Prospects

6.1. Research Conclusions

In teaching, integrating embodied cognition into the teaching objectives of KUDB, constructing the E-KUDB teaching objective model, and formulating corresponding teaching objectives, emphasizing the synergy of multiple senses in real situations to promote deep understanding and transforming abstract knowledge into perceptible and operable physical and mental experiences. In teaching, the unity of "doing, thinking, speaking, and acting" was achieved, and the integration of body and mind was accomplished. During this process, knowledge was internalized and transferred, significantly improving learning efficiency and effectively promoting the achievement of core competencies.

6.2 Future Prospects

The research integrates embodied cognition into project-based learning, constructed the E-KUDB teaching objective model and the project-based learning model under the perspective of embodied cognition, and applied it to the junior high school information technology curriculum to cultivate students' core competencies. Future research can be further deepened and expanded. Firstly, in the evaluation aspect, corresponding evaluation indicators and scales need to be set to make the results more reliable. Secondly, cross-disciplinary project expansion. Information technology courses inherently have cross-disciplinary attributes. In the future, the E-KUDB model can be extended to interdisciplinary projects in subjects such as science, mathematics, and art to explore how embodied cognition can play a mediating role in the integration of different subject knowledge and form a scalable cross-disciplinary embodied project design framework. Thirdly, the cross-grade application of the E-KUDB model. This research focuses on the junior high school stage. Subsequently, it can be extended to the upper grades of primary school and the senior high school stage to investigate the influence of students' physical development levels and cognitive characteristics on the design of embodied teaching objectives at different age groups.

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