International Journal of New Developments in Education
ISSN 2663-8169 Vol. 8, Issue 6: 68-74, DOI: 10.25236/IJNDE.2026.080611

A Five-Stage BUILD Teaching Model for Hierarchical Cognitive Thinking and Inquiry-Based Learning

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Abstract: *Students are often limited by rigid thinking and rote learning in current higher education. The rigid thinking and rote learning make it difficult for them to effectively solve complex problems. Moreover, teachers lack systematic and practical teaching methods to guide students to address this dilemma. In this paper, an innovative BUILD teaching model based on the theory of hierarchical cognitive thinking and inquiry-based learning is proposed. This model consists of five core stages and provides a progressive teaching implementation path. Specifically, the model aims to remove students' cognitive barriers and stimulate their desire for inquiry in the "Breaking" stage. In the "Unifying" stage, teachers guide students to construct a systematic knowledge framework through integration and unification. Students are encouraged to dissect the essence of theoretical concepts and reconstruct them through targeted inquiry in the "Inquiring" stage. A comprehensive evaluation strategy with multidimensional feedback is designed for reasonable assessment of students' learning outcomes in the "Learning-Assessment" stage. In the "Developing" stage, students can further get continuous improvement in knowledge and abilities through maintenance strategies. This model can help to establish students' scientific thinking methods and improve their ability to solve practical learning problems.*

Keywords: *Rigid Thinking; Rote Learning; BUILD Teaching Model; Hierarchical Cognitive Thinking; Inquiry-Based Learning*

1. Introduction

It is crucial to cultivate students to handle complex problems in current higher education. However, students are often limited by rigid thinking patterns. These cognitive rigidities are often reinforced by the traditional paradigm of rote-learning[1]. This results in students lacking independent thinking and initiative in inquiry-based learning. Therefore, students face significant challenges in solving complex problems. As introduced in many literatures, the inquiry-based learning emphasizes the student-centered exploration and critical questioning[2]. However, its practical application is still insufficient. Students often find it difficult to go beyond surface understanding and lack the cognitive strategies required for in-depth exploration in their learning process.

Additionally, teachers also face similar dilemmas. Although most teachers have realized the limitations of rigid thinking and rote-learning, they lack a systematic and practical teaching method to guide students in overcoming such cognitive barriers. Existing teaching methods often only provide scattered coping strategies. Therefore, most classrooms have not yet achieved the key transformation from passively receiving knowledge to actively thinking independently. One of the most notable features for the transformation is the hierarchical cognitive thinking[3]. How to integrate the training of hierarchical cognitive thinking into the entire teaching process is still a challenging issue for teachers[4].

To address this practical dilemma, an innovative BUILD teaching model based on cognitive psychology and inquiry-based learning theory is proposed. This model comprises five core stages and outlines a progressive teaching implementation path. The five stages are "Breaking", "Unifying", "Inquiring", "Learning-Assessment", and "Developing". It aims to transform the learning experience from a static accumulation of facts to a dynamic process of thinking and cognitive growth. This model can not only contribute to enriching the theoretical system of inquiry-based learning but also provides an operable and replicable teaching method for talent cultivation in higher education.

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2. Hierarchical Cognitive Thinking and Inquiry-Based Learning

Rigid thinking is often referred to the mental set or functional fixation in cognitive psychology. It represents a state in which an individual relies on the established patterns to solve problems and restrains creative solutions[5]. In higher education, this manifests as students adopting rote memorization strategies for complex or ill-structured problems. It results in the difficult for students to adapt to new environments. According to the schema theory, learning occurs when new information is integrated into existing cognitive structures. However, rigid thinking hinders the necessary reorganization or adaptation of these patterns. To break this rigidity, teachers should induce the cognitive conflict and motivate students to dismantle outdated thinking patterns before constructing new ones.

2.1. Hierarchical Cognitive Thinking

Traditional inquiry-based learning encourages exploration but often lacks a structured process for deepening cognition. This study introduces the concept of “bamboo shoot peeling” (BSP) to hierarchical cognitive thinking. It is a metaphor derived from the process of peeling bamboo shoots layer by layer to reach the core. This is an active analysis and cognitive process representing the process of learning from surface phenomena to basic principles. Unlike linear inquiry, the hierarchical cognitive thinking requires repeated questioning. Each answer will generate a deeper and more complex question and aim to cultivate students’ critical students’thinking and metacognition[6].

Moreover, hierarchical cognitive thinking can help students to build a systematic and structured knowledge system and avoid the fragmented accumulation of knowledge. It enables students to quickly identify the core contradictions, break down the problem dimensions and determine the solution approach in solving complex problems. Moreover, it enhances students’ critical thinking abilities and help them to break through the limitations of superficial cognition and form essential judgments about problems through in-depth, layer-by-layer exploration. The application of hierarchical cognitive thinking can transform students from passive knowledge recipients to active knowledge organizers in the teaching process and establish a solid knowledge foundation for cultivating their innovation and practical abilities.

2.2. Inquiry-Based Learning

Inquiry-based learning is a problem-oriented and collaborative learning-supported active learning model. Unlike the traditional active learning path from theory to practice, it follows a reverse logic of problem, inquiry, theory, verification, and innovation. Students are encouraged to start with specific practical problems from industry and daily life. They need to actively explore the theoretical essence behind the problems through independent thinking and collaborative discussion. When dealing with complex problems, they can propose solutions and implement innovative practices.

The main characteristics of inquiry-based learning are reflected in three dimensions. First, in order to make learning more targeted and practical, inquiry-based learning is problem-oriented learning process[7]. Practical industry problems and cutting-edge discipline problems can be taken as the starting point. Second, inquiry-based learning is a self-constructed learning process[8]. Students no longer accept theoretical knowledge passively but construct their own knowledge system independently through literature review, experimental operation, group discussion and other methods. This tends to realize the internalization and absorption of knowledge. Third, inquiry-based learning is also a learning path to innovative application. The target of inquiry-based learning is not only to impart basic knowledge to students, but guide student to find innovative solutions to problems and realize the flexible application of knowledge through hierarchical cognitive thinking.

Although there are many advantages for hierarchical cognitive thinking and inquiry-based learning, the practical application is still insufficient in current higher education. Therefore, it is necessary to introduce a corresponding teaching method with an entire theoretical framework and implementation path.

3. Five-Stage BUILD Teaching Model

To bridge the gap between educational theory and classroom practice, this paper introduces a five-stage BUILD teaching model. Based on the concepts of hierarchical cognitive thinking and inquiry-based learning, this model conceptualizes knowledge transfer as a systematic effort to build a cognitive edifice in students’ minds. Generally, building a house follows a logical sequence of creatively preparing the site,

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establishing a stable framework, perfecting internal functions, conducting quality assurance checks, and performing long-term durability maintenance. Similarly, effective learning requires a parallel structural process. The BUILD teaching model operates this architectural metaphor as five core stages. The five stages include "Breaking", "Unifying", "Inquiring", "Learning-Assessment", and "Developing". All stages are progressive and interconnected. The BUILD teaching model adheres to the teaching principles of motivation, knowledge construction, in-depth inquiry, effectiveness verification, and continuous consolidation.

3.1. Breaking (B)

The "Breaking" stage is a key entry point in the BUILD model. It is carefully designed to remove students' cognitive barriers and stimulate their desire for independent thinking and inquiry. Moreover, it aims to stimulate students' intrinsic motivation and rouse their inquiry-driven curiosity. Therefore, it is necessary to establish a clear connection between curriculum content, real-world applications, disciplinary frontiers, and students' existing cognitive frameworks. In order to facilitate the transition of students' cognition from passive acceptance to active participation, this stage is subdivided into three steps including context-driven learning, problem-oriented heuristic, and objective framework.

The context-driven learning anchors the abstract theories in specific application cases[9]. Teachers can utilize various teaching tools to illustrate the practical application of course concepts such as immersive scenario reconstructions, in-depth industry case studies, and demonstrations of cutting-edge technologies. This approach helps students understand the utility of knowledge intuitively. The selection of application cases needs to align with course objectives to enhance authenticity and engagement. Therefore, the attractive and interesting application cases from our daily life and industrial production are a good choice. However, it is insufficient to induce students' deep thinking and cognition with merely presenting these cases. Instead, it aims to reveal the limitations of students' current understanding and create prerequisites for the next stage.

The problem-oriented heuristic aims to present a series of guiding questions based on these selected cases and construct students' cognitive conflict. Therefore, teachers need to utilize the given context to formulate guiding questions intrinsically linked to the core curriculum. These questions should be carefully designed to be both inspiring and intellectually challenging. Moreover, they must align with students' existing knowledge structures and manifest the gap between new cognition and traditional cognition. The problem-oriented heuristic can transform the passive observation of the previous step into active investigation. For example, in the teaching process of the IO port P0 of 80C51 microcontroller[10], teachers can use students' prior knowledge that the P1 port can directly light up LEDs to form their misconception that all IO ports have the same structure and usage. Only switching the control port from P1 to P0 leads to an abnormal phenomenon that the LED on the P0 port fails to light normally. The first progressive question about why the P1 port can drive LEDs normally while the P0 port cannot when the hardware and program remain unchanged is designed. This triggers students' initial cognitive conflict and guide students to explore the P0 port's unique structure.

Based on the first two steps, the last step tends to construct a macro-framework of course content in students' cognition. Teachers need to clearly describe the learning objectives, core knowledge areas, and target competency outcomes. For example, the learning objectives the IO port P0 require students to distinguish the structural differences between the P0 port and other IO ports. The core knowledge areas cover the open-drain output feature, the absence of internal pull-up resistors, and the application rules of P0 port in input and output modes. The target competency outcomes enable students to correctly match peripheral circuits with P0 port and independently complete circuit connection with external pull-up resistors. The objective framework can effectively transform the open-ended questions from the previous step into a concrete roadmap. This provides a comprehensive cognitive map for students and clarify the fundamental questions of "what to learn", "how to learn", and "what standards to achieve". This ensures that students' cognition is not only motivated by the initial context and heuristic questions but also directed towards clear and measurable learning goals.

In the "Breaking" stage, the driving force of instruction tends to a fundamental shift compared with traditional paradigm. Teachers act as facilitators and scenario architects to create environments that stimulate students' thinking rather than simply provide them course content directly. Instead, students become active participants and deeply engaged in the discourse of case analysis and problem-solving. Such transformation of roles between teachers and students breaks down traditional feeding style classroom. This collaborative ecosystem can effectively catalyze a shift from extrinsic compliance ("I learn because I have to") to intrinsic motivation ("I learn because I want to") and lay the foundation for

ISSN 2663-8169 Vol. 8, Issue 6: 68-74, DOI: 10.25236/IJNDE.2026.080611

Students' hierarchical cognition thinking and inquiry-based learning.

3.2. Unifying (U)

The "Unifying" stage represents the transition from breaking rigid thinking to hierarchical cognition thinking. This stage is specifically designed to guide students in constructing and unifying a structured learning framework. This is analogous to building the main structure of a house. The learning framework enable students to have a comprehensive understanding of the entire course content from a macro perspective. The construction of learning framework needs to consider a synergistic dual outcome including the systematic reconstruction of knowledge and the internalization of hierarchical cognitive thinking. An implementation strategy to construct the learning framework in students' cognition can be carried out through the following steps.

Teachers conduct a comprehensive analysis of the course content and break down it into several key problems. These problems are taken as the load-bearing pillars supporting the learning framework. These problems should cover the essential points of the course and keep a progressive logical relationship. Therefore, the design of problems should strike a balance between fundamental and inquiry-based elements. The basic problems are about core concepts and fundamental theories whereas inquiry-driven problems are about knowledge interconnections and logical analysis.

Teachers need to integrate the training on hierarchical cognitive thinking and inquiry-based learning into the pathways of solving these problems. For example, when learning the IO ports of 80C51 microcontroller, teachers can decompose this core knowledge into a series of problems to help students establish a systematic knowledge logical system in their cognition. These problems can be designed as follows. Why can P1-P3 ports directly drive an LED to light up normally without any external components? Why does the P0 port fail to drive the LED normally as the P1-P3 port? What role does an external pull-up resistor play in enabling the P0 port to work normally? What are the essential differences in their internal structures? These interlocking problems not only break down the knowledge of IO ports into accessible and progressive inquiry points but also outline the skeleton of the course content.

In the process of exploring and solving these problems, teachers facilitate the integration of different knowledge points and guide students to map the lateral connections and vertical progression. Students can gradually sort out the logical connection between the structures and construct a systematic cognitive framework. Therefore, the learning process is not only accumulating fragmented information but also to build a structured knowledge system.

In general, the learning framework built in this stage is equivalent to the outermost layer of hierarchical cognitive thinking. It allows students to grasp the skeleton of the course content from a macro perspective, help them to draw a mind map in their cognition. This stage serves as a foundation for subsequent deeper thinking and learning.

3.3. Inquiring (I)

After establishing the learning framework from a macro perspective, the "Inquiring" stage focuses on the in-depth exploration of the course content from a micro perspective by solving the pre-designed problems one by one. This is analogous to the details of decoration after the main structure of a house is completed. In this stage, teachers guide students to delve into the knowledge core and essential connotation hidden behind each problem and realizes the deepening from framework cognition to detailed mastery. Specially, an implemented path is introduced as follows.

Teachers need to analyze and extract the fundamental theoretical principles and key skill requirements related to each problem based on the previously constructed knowledge framework. This process requires defining specific inquiry trajectories for students to identify the focus areas and potential cognitive bottlenecks. Teachers ensure that students' learning exploration is not scattered but targeted and efficient by clarifying these directions.

After determining the inquiry trajectories, it is necessary to design immersive learning activities for each problem to guide students to personally experience the cognitive conflict. These activities can be in-depth case studies, hands-on experiments, project-based design tasks, and systematic literature reviews. For example, teachers can design comparative experimental hands-on activities in teaching IO ports to allow students to build circuits, burn programs, and observe phenomena by hand. Students observe the experimental phenomenon that the P0 port fails to light up the LED as Other IO ports. Therefore, they can intuitively and concretely experience the cognitive conflict and transform abstract logical contradictions into observable and perceptible hardware phenomena.

Teachers design a series of progressively deeper and interconnected questions based on the cognitive conflicts exposed to students. These questions are used to guide students to dissect the surface of contradictions layer by layer and delve into the underlying causes and mechanisms of cognitive conflicts. Students are organized into several groups to engage in autonomous investigation and collaborative discussions. Teachers encourage them to combine their existing knowledge to deeply analyze the problem and propose a preliminary solution. It is worth noting that instead of forcing students to produce standard answers, the emphasis is placed on fully preserving students' original thinking processes.

Each group presents their solutions and shares the inquiry process and conclusions through classroom reports or interactive discussions. Teachers comment on and summarize the results of each group and identify the key points and shortcomings in the inquiry process. This can help students to deepen their understanding of theoretical knowledge and promote their knowledge internalization and professional skill improvement. Subsequently, teachers encourage students to optimize their solutions and further verify them repeatedly. In the cyclical exploration process of hypothesis, verification, refutation, correction and re-verification, students can be trained to independently construct the internal thinking logic and the cognition of problem essence rather than directly instilled by the teacher.

As described in the above process, this stage emphasizes students as the main participants in learning instead of being a passive receiver. However, teachers act as the classroom designers and organizers. They are responsible for the overall instructional design and ensuring the smooth implementation of the entire process. Teachers guide students to experience and emulate the cognition process from finding problems to solving problems. Students' cognition is no longer superficial and fragmented but highly logical and actively grasp the essence of the problem when they equipped with hierarchical cognitive thinking and inquiry-based learning. This is also crucial for students' lifelong learning.

3.4. Learning-Assessment (L)

The "Learning-Assessment" stage represents the key convergence of formative feedback and summative competence assessment. This is analogous to the quality inspection and acceptance process after a house is built. It aims to assess not only the students' mastery of knowledge but also the abilities of hierarchical cognitive thinking and inquiry-based learning. The students' mastery of knowledge generally can be well assessed according to examination. However, the abilities of hierarchical cognitive thinking and inquiry-based learning are abstract and difficult to quantify. This stage adopts the learning-assessment concept and moves beyond the traditional exam-centric paradigm. The learning-assessment concept constructs a robust and multidimensional assessment ecosystem designed to optimize the teaching and learning process. The implementation strategy can be carried out as follows.

The assessment is conducted through integrating case studies. The selection of cases needs to tightly integrate with academic depth, operability, and innovative potential. Moreover, these cases are specifically designed to test students' abilities in knowledge application, complex problem solving, and creative synthesis. Students must deploy the theoretical frameworks, cognitive strategies, and technical skills acquired throughout the course to deconstruct these cases and ultimately propose feasible solutions or innovative designs. This ensures that the assessment is not an abstract exercise but a simulation of real-life professional challenges.

A dedicated demonstration platform is necessary for making the thinking process visible. Student groups should elucidate their analytical processes, conclusions, and proposed solutions through various formats such as formal classroom reports, prototype demonstrations, and oral defenses. Crucially, these demonstrations must clearly demonstrate the application of hierarchical cognitive thinking and inquiry-based learning. For example, in the learning of 51 single-chip microcontroller I/O ports, teachers can assess students' hierarchical cognitive ability by examining their logical progression from basic concept understanding to principle analysis and practical system application. Meanwhile, their capacity for inquiry-based learning is evaluated based on how students raise questions about port configuration limitations, design verification experiments and optimize debugging schemes independently. This ensures that the assessment focuses not only on the final outcomes but also on the logical coherence, methodological rigor, and innovative quality of the underlying thought processes.

Multiple assessments are implemented for holistic evaluation of student learning outcomes. The assessments are combined with teacher evaluation, peer evaluation, and self-evaluation. The evaluation indicators are developed from multiple dimensions including knowledge acquisition, application of thinking, practical ability, innovation ability and collaboration ability. During the assessment process, the

ISSN 2663-8169 Vol. 8, Issue 6: 68-74, DOI: 10.25236/IJNDE.2026.080611

focus is on affirming and encouraging students' innovative points and the inquiry process itself rather than simply focusing on the correctness of the results.

The assessment results are served as feedback and contribute to optimizing the teaching and learning process. Teachers systematically analyze the assessment results to identify patterns in student performance and highlight strengths in knowledge integration. Moreover, teachers point out the weaknesses in cognitive application or skill execution. This can provide students with the constructive and timely feedback and offer feasible suggestions for improvement. Meanwhile, teachers engage in reflective practice and diagnose teaching gaps using these insights. This ensures the dynamic evolution of the teaching and learning process according to students' requirements.

3.5. Developing (D)

The "Developing" stage aims to consolidate and deepen the established students' knowledge, abilities, and thinking methods. This analogy is analogous to the post-construction maintenance of a house. It aims to enable students to further master the application of hierarchical cognitive thinking and inquiry-based learning methods through independent after-school learning. Moreover, it tends to establish a regular learning and communication mechanism and organically connect the classroom learning with after-school improvement. A specific implementation strategy is introduced as follows.

Teachers need to design differentiated after-school independent learning tasks based on students' learning performance at first. These tasks should combine fundamental and challenging aspects to meet the learning needs of students at different levels. For example, the fundamental tasks are selected as knowledge review and mind mapping, and the challenging tasks are generated from the cutting-edge research and innovative project design. It is worth noting that creating mind maps can help students to build a systematic knowledge framework and visualize the thinking process.

Teachers can establish online learning and discussion platforms to facilitate student communication and discussion after class. Students can raise questions encountered during learning, share learning experiences, and exchange research results on the platform. Teachers can regularly answer questions, provide guidance, promote online discussions, and create a regular online learning atmosphere.

Furthermore, it is significant to broaden students' cognitive horizons and practical scenarios with encouraging students to combine after-class leaning with real-life applications and industry. Teachers need to provide students with multidimensional practical platforms rather than only simple homework such as small-scale innovation projects, subject competitions, and curriculum design. They should guide students to actively participate in these platform activities and apply their knowledge and thinking methods to solve problems. This can help students to achieve flexible application of knowledge and continuous improvement of abilities.

Students are encouraged to summarize their after-class learning including reviewing the knowledge, ability enhancements, and thinking progress they have gained during the learning process. This enables them to clearly recognize their growth and shortcomings. Based on the continuous practice and application, the active hierarchical cognitive thinking and inquiry-based learning methods can be transformed into students' regular thinking patterns and learning habits. Consequently, these thinking patterns and learning habits can gradually achieve the true internalization of thinking and sustainable development of comprehensive abilities.

The "Developing" stage is an extension and sublimation of the entire teaching model. It tends to break the limitations of the traditional classroom where learning ends with the class and enables students to continuously improve their knowledge, skills, and thinking abilities.

4. Conclusions

This paper provides a theoretical framework and implementation path for improving students' abilities to handle complex problems in higher education practice. A five-stage BUILD teaching model has been proposed based on the theories of hierarchical cognitive thinking and inquiry-based learning. This model introduces a systematic approach to addressing the long-standing challenges of rigid thinking and rote-learning. The BUILD model is characterized by its five-stage architecture including "Breaking", "Unifying", "Inquiring", "Learning-Assessment", and "Developing". Specifically, this model aims to promote the reconstruction of cognitive structures. The synergistic effect between the "Breaking" and "Unifying" stages helps student to break down their deeply ingrained thinking patterns, stimulate their

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intrinsic learning motivation, and guide them to build a systematic knowledge framework. The “Inquiring” and “Learning-Assessment” stages promote the holistic development of students’ abilities in finding, analyzing, and solving problems. In these stages, students are guided to use hierarchical cognitive thinking to deconstruct and solve each problem related to the learning framework. Moreover, a multi-dimensional assessment approach is used to evaluate students’ learning outcomes. The learning outcomes are taken as the feedback to improve teaching and learning process. The “Development” stage extends the learning cycle beyond the classroom. It integrates the mechanisms for continuous reflection, self-improvement, and cognitive schema internalization and ensures students’ continuous growth and development. This model can help to transcend the limitations of traditional linear teaching and construct a dynamic teaching ecosystem that transforms passive knowledge acquisition into active cognitive construction. Moreover, it brings a profound transformation in educational paradigms from fragmented knowledge accumulation to the comprehensive cultivation of thinking, abilities, and qualities. The BUILD model not only enriches the theoretical foundation of inquiry-based learning methods but also provides teachers with a replicable and actionable blueprint for teaching reform.

Acknowledgements

This work is supported by the University-Industry Collaborative Education Program (241205589020507): “AI-Enabled Teaching Reform and Practice of Digital Media Courses”.

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