Research on the Cultivation Path of Design Thinking in China's Basic Education Stage Based on Attribute Construction

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1 Introduction

The cultivation of innovative talent is the core goal of talent development in today's era. The Chinese government attaches great importance to the cultivation of innovative talents, with the "National Medium-Term and Long-Term Education Reform and Development Plan Outline (2010–2020)" [21], the 2016 "National Innovation-Driven Development Strategy Outline" [10], and the 2019 "China's Education Modernization 2035" [14] all emphasizing the crucial role of innovative talent in national development.

Cognitive development is the core of cultivating innovative talent. Enhancing cognitive abilities is hailed as an effective way to address the challenges posed by the accelerated pace of knowledge update and the increasing complexity of the living environment. In 2014, the Ministry of Education of China first introduced the concept of core competencies as a strategy to promote a shift in talent development [5]. Against the backdrop of educational reforms transitioning from a "knowledge-based" to a "competency-based" curriculum, design thinking has attracted increasing attention from educational researchers and frontline teachers due to its human-centered approach, focus on cognitive ability development, and its ability to connect disciplinary knowledge with the real world.

However, the promotion of design thinking education in China's basic education stage faces several challenges. Although applied research in foreign countries is relatively mature, in China, relevant teaching practices are mainly concentrated in university-level design programs, while design thinking courses in basic education (i.e., primary and secondary schools) are still in the exploratory stage. Moreover, educators often focus more on course content design and subject integration at the knowledge level, neglecting the essential connotations of design thinking. Existing course development and implementation tend to remain superficial, lacking a systematic cognitive development framework [13]. At the same time, the complexity of design concepts and methods also hinders frontline teachers from truly understanding design thinking and grasping the key teaching points [20]. The issues regarding the cultivation of design thinking in basic education can be summarized into two main aspects:

- An unclear understanding of what design thinking is, with excessive focus on teaching forms rather than the underlying cognitive content;
- A lack of clarity on how to cultivate design thinking in the basic education stage, with insufficient consideration of the overall development path of cognitive skills.

In response to these issues, the core objective of this study is to conduct a systematic exploration of the pathways for cultivating design thinking from a theoretical perspective. This paper aims to construct a theoretical model of design thinking and provide a series of practical and feasible strategy recommendations for the development of design thinking curricula. This study will start with the theoretical connotations of design thinking and educational practices, using the concept of

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attributes as a thread, proposing a model of attribute-based cognitive units, and on this basis, reconstructing the design thinking model to form a theoretical framework with practical significance for educational practices. This model not only has fundamental philosophical importance but also offers practical guidance, providing frontline teachers with clear instructional strategies.

2 THEORETICAL CONNOTATIONS AND EDUCATIONAL PRACTICES OF DESIGN THINKING

2.1 Theoretical Connotations of Design Thinking

The formal use of the concept of Design Thinking began in 1987 with Peter G. Gowe's description of the design methodology for architects and urban planners [9], but its origins can be traced back further to the design methods movement of the 1960s. This movement emphasized the use of rational and scientific approaches in design project research. In this context, Herbert Simon, through logical reasoning, first proposed the idea of "design as a way of thinking or a specific science" and the concept of "the science of design" in 1969 [19], laying the foundation for the study of design thinking.

Subsequent scholars continued to explore the disciplinary positioning, practical methods, and cognitive patterns of design, contributing to the formation of the concept of design thinking. To bridge the gap between Simon's design science and design practice, Bruce Archer highlighted the distinction between designerly ways of thinking and communicating and traditional scientific or academic approaches [1]. Design thinking refers to the cognitive mode of designers, inherently tied to the nature of design work [8]. Donald A. Schon proposed that the essence of design is reflective practice [18]. In practice, design often begins with ill-structured problems rather than well-formed problems, and thus the ability to handle uncertainty, instability, uniqueness, and value conflicts is a crucial component of design thinking. Additionally, Richard Buchanan's discussions on wicked problems [4], Tim Brown's insights into the design thinking process and innovative problem-solving methods [3], and Roger Martin's analysis of the design of business [15] all contributed significantly to the development of design thinking methodologies.

The design thinking model is a concentrated manifestation of the exploration of design thinking's connotations and the innovation of design methods. Classic models of design thinking include IDEO's 3I Innovation Model [11], Stanford University's D.School EDIPT Model [11], the UK Design Council's Double Diamond Model [16], and Jeanne Liedtka's FOUR WHAT Model [12]. Among them, the Double Diamond Model, first published in 2004, has been widely applied in design research, design education, and design practice. The Double Diamond Model consists of four stages: Discover, Define, Develop, and Deliver. The most widely circulated versions are Dan Nessler's improved model proposed in 2016 and the updated version of the Double Diamond framework released by the UK Design Council in 2019. The former refines the specific divergent or convergent thinking methods in each of the four stages, while the latter emphasizes the importance of iterative cycles in design.

We can approach the connotation of design thinking from three perspectives: capability, methodology, and process.

- From the capability perspective, design thinking is a unique cognitive mode that integrates elements such as divergence and convergence, analysis and synthesis, human-centeredness, visualization, and iteration. It emphasizes understanding real needs from the user's perspective through empathy [16].
- From the methodology perspective, design thinking is a system of innovative problem-solving methods, integrating expertise from design, social sciences, engineering, business, and other fields. It incorporates human, technology, business, and natural factors into the overall problem-solving process
- From the process perspective, design thinking is a cognitive process that includes problem exploration, solution ideation, solution creation, and iterative testing, emphasizing the balance between imagery and abstraction, divergence and convergence, analysis and synthesis, and logic and intuition.

2.2 Design Education Practices in Basic Education Stage

Design education began as a craft-based apprenticeship system in the agrarian era, and later evolved into specialized education in the industrial era. It was formally established as a field of study in the late 20th century. With the advent of the knowledge network era, design thinking has attracted increasing attention from educators and practitioners due to its universality and distinctive cognitive form, aligning with the global demand for cultivating innovative talents. Design education, centered on cognitive education, has further developed towards design literacy education and general education, permeating the curriculum system of basic education (i.e., primary and secondary school stages).

In terms of cultivating design thinking at the basic education stage, various countries have distinctive curriculum designs. Germany's design education emphasizes solving practical problems, fostering students' independent thinking through vocational and technical education courses and hands-on practice. In Japan, aesthetic education is introduced from elementary school, utilizing diverse forms such as television programs to stimulate children's design thinking and creativity. The US K-12 design education framework focuses on stimulating students' everyday creativity through life-oriented teaching methods and practices that simulate the role of a designer, cultivating students' innovative thinking and problem-solving abilities [2, 17]. In the UK, design education develops students' creative and practical design skills through courses in Art and Design and Design and Technology.

China's design education at the basic education level began relatively late, with the introduction of the "Technology and Design" course for high school students in 2005, aimed at cultivating students' design abilities. In recent years, with the advancement of educational reforms, the cultivation of design thinking has increasingly gained attention. In 2017, the Ministry of Education issued the "Guidelines for Comprehensive Practical Activities in Primary and Secondary Schools", emphasizing guiding students to discover and solve problems from real-life situations through comprehensive practical activities, cultivating their problem-solving and innovative abilities. However, China's design education practice still faces challenges such as a lack of top-level curriculum guidance, loose curriculum structure, and formalized course activities. In practice, design thinking education should move away from knowledge-based teaching models, focus on cognitive development, and adapt to local conditions, exploring pathways for cultivating design thinking that suit China's national conditions and educational ecosystem.

3 Method

3.1 Research Purpose and Design

The present paper aimed to investigate how an attribute-based design thinking curriculum could cultivate students' design thinking abilities in basic education. The core goal was to determine whether and how such a curriculum improves students' creative thinking traits specifically adventurousness, curiosity, imagination, challenge-taking, and overall creativity —- in real school settings. To this end, we adopted a mixed-methods, action research design in authentic classrooms, combining qualitative and quantitative approaches . This design was largely quasi-experimental: we implemented the design thinking curriculum in selected classes (experimental groups) and observed changes relative to comparable classes not receiving the curriculum (parallel control groups). Given the authentic school environment, the study was not a tightly controlled laboratory experiment, but rather an exploratory field intervention under natural conditions . This allowed me to evaluate the curriculum's impact while acknowledging the diverse, uncontrollable variables in each school's ecology. This paper combined qualitative, holistic analysis with quantitative, focused analysis to evaluate the effectiveness of the intervention on students' thinking skills . In line with this approach, we formulated five specific hypotheses predicting that students' adventurousness, curiosity, imagination, challenge propensity, and overall creative thinking would improve significantly after the intervention.

3.2 Participants

The study involved a collaboration with five schools in Zhejiang Province, China, including primary and secondary institutions . These schools voluntarily participated as pilot sites for the new design thinking curriculum. In total, over two hundred students across upper elementary (grades 4–6), junior high (grades 7–8), and one high school class (grade 10) took part in at least one module of the course. For the quantitative component, we focused on two grade levels to form experimental-control comparisons. At the primary level, we selected 48 students total – 24 in an experimental class and 24 in a parallel control class – with both groups drawn from the same school and grade to ensure similar backgrounds . Similarly, at the junior high level, we selected 21 students in an experimental class and 21 in a control class (42 students total) for controlled comparisons. These students were of similar age and academic background within their schools. All participant groups were taught as intact classes (natural classes or elective clubs, depending on the school's implementation), and all students in the experimental classes received the design thinking curriculum as an intervention in addition to their regular coursework. The control (parallel) classes continued with the standard curriculum and did not receive the design thinking lessons, serving as baselines for comparison. Importantly, experimental and control students were recruited through the same channels within each school (e.g. from the same grade or program) to ensure they were comparable in general academic exposure. This helped control for school-specific factors – both groups followed the usual school program except that the experimental group had the extra design thinking course. Participant teachers included a team of trained instructors (4–5 per school) from diverse subject backgrounds (such as art, science, technology, and labor skills) who taught the design thinking lessons. These teachers worked closely with me and received supporting materials and guidance throughout the experiment.

3.3 Intervention (Curriculum and Procedure)

The intervention was a specially developed design thinking curriculum based on "attribute construction" theory. I designed a series of course modules intended to reconstruct design thinking processes around the concept of identifying and manipulating the "attributes" of problems and solutions. The curriculum was implemented over a span of roughly one and a half years (from late 2018 to mid-2020) , in alignment with a provincial initiative on design education. The program consisted of two main modules (Module A and Module B), each containing several project-based units that were tailored to different age groups and thinking skills. For example, at the primary level Module A included projects like "The Shape of Sound" (exploring sensory attributes by visualizing sounds) and "Attributes of Objects" (analyzing everyday objects' properties), while Module B included "Bionic Design" (learning from nature's attributes to inspire design) and "Gamified Design" (applying game-design principles) . At the junior high level, projects included more advanced challenges such as "Design Detective" (observing and improving real-world scenarios like school cafeterias or pickup areas) and "Brand Image Design" (creating product/brand prototypes using advanced tools) . Each project was grounded in students' daily life contexts to ensure relevance and engagement (e.g. solving problems in familiar school environments) . We provided participating teachers with detailed lesson plans, slides, student workbooks, and checklists to support fidelity of implementation . We coordinated the teaching schedule with each school: typically the design thinking classes were held as weekly elective periods or club activities, sometimes requiring double periods for hands-on work. Throughout the intervention, the teaching process alternated between “attribute divergence” and “attribute convergence” activities, following the theoretical model’s emphasis on expanding ideas and then narrowing them towards solutions. This paper actively monitored the implementation – often co-teaching or observing in the classroom – to ensure consistency and to make iterative adjustments based on feedback. The five experimental schools’ implementations varied (some classes were mixed-grade, some were within regular timetable vs. after school clubs), reflecting a microcosm of the diverse educational settings in the province . Despite this variability, all experimental classes completed the full set of design thinking projects for their module, roughly 8–10 class sessions per module on average, over the study period. Control classes did not partake in these projects. By the end of 2020, Module A and B had been taught and refined across the schools, providing a rich set of data on student outcomes.

3.4 Instruments and Measures

To quantitatively assess the impact of the curriculum, I employed the Williams Creativity Tendency Scale. This is a standardized creativity assessment that evaluates students across four dimensions of creative thinking – Adventurousness (willingness to take risks), Curiosity, Imagination, and Challenge (persistence in the face of difficulty) – and provides an overall creativity score. Each student in the experimental and control groups took this test as a pre-test (baseline) before the curriculum began and as a post-test after the curriculum was completed. The test was administered as a paper-and-pencil questionnaire (validated for school-age populations) under my supervision in classroom settings. In total, I collected 48 valid pre-test responses at the primary level (24 experimental + 24 control) and 42 valid pre-test responses at the junior high level (21 + 21) , and the same numbers of post-test responses for each group at the end of the program. The Williams scale yields quantitative scores for each creative trait; these served as the dependent measures in our analysis of effectiveness.

For qualitative insights, I used several instruments and data collection techniques. One key tool was an Observation Checklist/Record Sheet that I and other observers (including collaborating teachers or visiting educators) used during classes . This checklist helped systematically record classroom events, student engagement, use of design thinking tools, and notable behaviors or challenges. It also had space for observers to write down real-time suggestions for improving the lesson, providing immediate formative feedback for curriculum refinement. Additionally, I conducted semi-structured interviews with the teachers immediately after each lesson or project session. These were open-ended, reflective conversations where teachers could share their teaching experience, observations of student performance, and any difficulties or suggestions . I encouraged teachers to be candid about what worked or didn’t, and I took detailed notes (and occasionally audio recordings) of these interviews. This ongoing dialogue allowed me to adjust subsequent lessons (action research’s iterative improvement) and also served as qualitative data on teacher perceptions.

To capture the student perspective, I distributed feedback questionnaires and held informal group discussions with students at the end of the module. The questionnaires prompted students to rate and comment on their experiences – for example, asking how much they enjoyed the projects, what they felt they learned, and any suggestions or difficulties they encountered. Some students also provided written reflections as part of class assignments. Moreover, I gathered input from external experts and observers: education researchers and design experts from the provincial education department periodically observed the classes (some in person, some via live video) and provided their feedback. Toward the end of each module’s implementation, I organized a formal expert panel review meeting where these experts, along with school principals and lead teachers, evaluated the curriculum outcomes and gave professional critiques (this process is detailed later as part of results) . All these sources – observation notes, teacher interviews, student feedback forms, and expert comments constituted the qualitative data for the study.

3.5 Data Collection Procedure

Before the intervention, I administered the creativity pretests to all selected experimental and control students, with the assistance of their homeroom teachers. The testing sessions were done in a single class period per group, and the anonymity and purpose of the test were explained to students. Once baseline data were collected, the design thinking curriculum was taught in the experimental classes over the course of the semester/year as described. I (or members of my research team) observed nearly every session of the design thinking classes, using the checklists and taking field notes. After each class, I held brief post-lesson interviews with the instructor (and sometimes a few students) to gather immediate impressions. These reflections often led to minor tweaks in upcoming lessons (for example, adjusting the difficulty of a task or providing additional examples if a concept wasn’t understood). Midway through and after completing each project, students sometimes presented their design outcomes, which were documented via photos or videos. I collected student artifacts (design sketches, prototypes, posters, etc.) for further analysis of their creative process. At the end of the full curriculum (after all projects were completed, roughly 8–12 weeks of instruction), I administered the post-test (Williams scale) to the same experimental and control groups under similar conditions as the pre-test. Simultaneously, I distributed feedback surveys to the experimental students and interviewed the teachers in depth about the overall course impact. Finally, the expert review meeting was convened after Module A and Module B implementations, where I presented the collected results (student works, test scores, observations) and experts provided commentary, which I recorded. This multi-faceted data collection ensured triangulation: quantitative test scores to measure cognitive outcomes, and qualitativ observations and feedback to understand the how and why behind those outcomes.

3.6 Data Analysis

This paper analyzed the quantitative data using statistical tests appropriate for a pre-test/post-test control group design. Specifically, we performed independent-samples t-tests to compare the experimental vs. control groups' baseline scores (to verify they started at equivalent levels). After confirming baseline equivalence, we used paired-samples t-tests to examine pre- vs. post-test changes within each group. This included testing whether the experimental class's scores improved significantly after the curriculum, and whether the control class's scores changed over the same period. The significance level was set at $p < .05$ (with $p < .01$ as highly significant). These tests were conducted for each of the four creativity dimensions and for the overall creativity score. We also computed descriptive statistics (means and standard deviations) for all measures at pre- and post-test. The quantitative analysis was done using SPSS software and was reviewed with an external statistics advisor to ensure accuracy. For the qualitative data, this paper employed a thematic analysis and evaluative rating approach. First, we read through all observation notes and interview transcripts to identify recurring themes or issues (such as student engagement, time management, resource needs, etc.). We then organized the qualitative feedback according to key aspects of the curriculum's effectiveness. Based on discussion with expert collaborators, we distilled the qualitative outcomes into three broad categories (curriculum design, student learning, and implementation logistics), each further divided into specific dimensions (six in total) for evaluation. Those six qualitative dimensions were: 1) Curriculum Design – theoretical coherence, 2) Student Growth – observable outcomes, 3) Content Difficulty (comprehensibility), 4) Materials Supportiveness, 5) Teaching Arrangement Compatibility, and 6) Content Extensibility. Using rubrics developed for each dimension, we converted the various feedback into rating scores (on a 5-point scale) for each project and then averaged them to summarize overall performance in that dimension . For example, if multiple observers and teachers commented on how well a project's design aligned with the theory, we assigned a score for "Curriculum Design" for that project; if students demonstrated tangible creative outputs, we rated "Student Growth," and so on. The present paper also coded open-ended comments to contextualize these scores. This combined approach yielded both numeric indicators (average ratings) and descriptive insights for the qualitative results. Finally, we synthesized all findings to draw conclusions about the efficacy of the design thinking curriculum and to identify areas for improvement.

4 Result

4.1 Quantitative Results (Creativity Test)

The pre- and post-test data provided clear evidence of the curriculum's impact on students' creative thinking. At the primary school level, the experimental and control classes started with statistically equivalent creativity levels. Before the intervention, the mean overall creativity score in the primary experimental class was 110.88 (SD 8.40), virtually the same as the control class's 110.00 (SD 8.87) . Similarly, on each creativity dimension (Adventurousness, Curiosity, Imagination, Challenge), there were no significant differences between the two classes at pre-test (independent t-tests, all $p > .50$) . For instance, the experimental vs. control pre-test means for Adventurousness were 23.88 vs. 24.17, for Curiosity 32.67 vs. 32.13, etc., with none of these gaps being statistically significant ($p = 0.54$–0.73) . These results confirmed that the two groups were well-matched at baseline. After the design thinking course was implemented, however, the primary experimental class showed dramatic improvements on all measures, whereas the control class showed little to no change. The experimental group's post-test scores were higher than their pre-test scores in every creativity dimension (see Figure 6.7), and paired t-test analysis revealed that all these gains were statistically significant ($p < .01$) . In contrast, the primary control group's scores at post-test remained approximately the same as at pre-test (Figure 6.8), with no significant differences detected (paired tests, all $p > .05$) . To illustrate, the experimental class's Overall Creativity mean increased from 110.88 to 135.58 after the course – a gain of about 25 points – which was highly significant (paired $t(23)$ 19.65, $p < .01$) . By contrast, the control class's overall score changed only marginally (110.00 to 112.21) and this change was not statistically significant ($p = .34$) . Likewise, the experimental group's Adventurousness score rose from 23.9 to 29.2 ($p < .01$), whereas the control group's stayed around 24.2 to 25.0 ($p = .09$, n.s.) . We observed the same pattern for Curiosity (experimental increased from 32.7 to 38.8, $p < .01$; control 32.1 to 32.7, $p = .61$), Imagination (experimental 27.2 to 35.1, $p < .01$; control 26.8 to 26.9, p = .93), and Challenge (experimental 27.2 to 32.5, $p < .01$; control 26.9 to 27.6, $p = .19$) . All four creative thinking traits improved significantly in the primary students who took the design thinking course, whereas none of these traits showed a significant change among students who did not take the course. These findings strongly support the effectiveness of the intervention at the primary level – the primary experimental group demonstrated a broad enhancement of creative thinking propensity, confirming Hypotheses 1 through 5 for this cohort .

At the junior high school level, the results exhibited a very similar trend. The experimental and control classes began with nearly identical creativity scores: for example, the pre-test Overall Creativity means were about 106.86 for the experimental class and 106.52 for the control class, with no significant difference between them ($p = .91$) . There were also no significant pre-test differences on Adventurousness, Curiosity, Imagination, or Challenge (all $p > .25$), indicating the groups were comparable at baseline . After the implementation of the design thinking curriculum in the junior experimental class, marked improvements were observed in that group's scores, whereas the control group again remained flat. The junior experimental students' post-test scores exceeded their pre-test scores across all measured dimensions (Figure 6.10), and these gains were statistically significant at the 0.01 level . For instance, the experimental group's Overall Creativity jumped from roughly 106.5 before to 135.6 after – an increase of nearly 29 points (paired t(20) 23.97, $p < .01$). In contrast, the control group's overall score showed a minor change (106.9 to 109.6) which was not statistically meaningful ($p = .052$) . The gains for the junior experimental class were significant on all sub-scales as well: Adventurousness rose from 23.7 to 29.2 ($p < .01$), Curiosity from 30.8 to 38.2 ($p < .01$), Imagination from 25.6 to 35.2 ($p < .01$), and Challenge from 26.4 to 32.9 ($p < .01$) . By comparison, the junior control class showed no reliable changes in Adventurousness (24.4 to 25.1, $p = .15$), Curiosity (30.1 to 30.8, $p = .13$), Imagination (26.5 to 27.1, $p = .49$), or Challenge (25.9 to 26.6, $p = .30$) over the same period . In sum, the junior high experimental group experienced significant improvements in creative thinking across the board, whereas the control group did not – mirroring the primary-level findings. These results again confirm all five hypotheses and indicate that the design thinking curriculum had a robust positive effect on students' creativity at the junior high level .

Taken together, the quantitative evidence strongly supports the conclusion that participation in the attribute-based design thinking course significantly enhanced students' creative thinking abilities. Students who underwent the design thinking projects became more willing to take intellectual risks, more curious and inquisitive, more imaginative in their thinking, and more eager to tackle challenges, as reflected by their increased scores. The fact that control groups (who did not take the course) showed no similar gains suggests that thes improvements can be attributed to the intervention rather than general maturation or school effects. Nonetheless, we remain cautious in interpreting causality: despite efforts to match the groups and keep their regular instruction constant, it is possible that unmeasured factors (e.g. differences in home environment or teacher style) contributed in part to the outcomes . However, the consistency and magnitude of the observed gains in the experimental groups – with all dimensions of creativity improving significantly ($p < .01$) – indicate a strong association with the design thinking curriculum. The quantitative results, therefore, provide compelling evidence that my curriculum effectively cultivates key aspects of design thinking (as operationalized through creative thinking tendencies) in basic education students.

4.2 Qualitative Results (Observations and Feedback)

Qualitative findings from classroom observations, interviews, and surveys complemented the test results by illustrating how the curriculum influenced students and identifying areas for improvement. Overall, the feedback from teachers, students, and expert observers was very positive, highlighting tangible student growth in creative thinking skills and engagement. Teachers reported that students in the design thinking classes were highly engaged and demonstrated clear, observable progress in their approach to problem-solving. Throughout the projects, students learned to use design thinking tools (such as mind-mapping, AEIOU observation grids, and rapid prototyping techniques) that align with the "attribute" approach, and they applied these tools to tackle design challenges effectively . In both the process and final outcomes, students showed notable creative performance – for example, they brainstormed more ideas, made novel connections between concepts, and produced inventive design solutions (such as creative product prototypes and imaginative service designs) by the end of each project . Many students who were initially quiet or hesitant began to take initiative during the hands-on activities. According to teacher testimonies, students' confidence and enthusiasm grew visibly: they became more comfortable with open-ended problems and more adept at iterating on their ideas. One teacher described how students' thinking "seemed to sprout wings" once given concrete examples – initially some learners felt a bit lost with an abstract task, but after minimal guidance and seeing one example, "their imagination took off" in developing their own solutions . Such observations were common across schools, indicating that the curriculum successfully engaged students in creative thought.

Importantly, students themselves responded very well to the design thinking course. In end-of-class feedback, a majority of students expressed excitement and interest in the activities, often commenting that the lessons were "different from regular classes" and allowed them to think freely. Some even said they felt like "real designers" when working on projects. Many students wished the classes could continue or be allocated more time. Indeed, several students suggested having longer sessions to work on their designs, more materials or examples to spur ideas, and even asked if teachers could join in the creative making process with them . This feedback reflects a high level of engagement – students were so invested in the creative tasks that they wanted additional time and collaboration to explore them further. Such enthusiasm is a strong qualitative indicator of the curriculum's positive impact on student motivation and creative mindset.

To systematically evaluate the qualitative outcomes, I synthesized feedback across six key dimensions. The first dimension, "Curriculum Design: Continuity of Form and Theory," received an average rating of 4.3 out of 5 across all projects . This high score indicates that the design of the curriculum effectively translated theoretical principles into practical teaching activities. In other words, the way I structured each project (with clear objectives, focal problems, and alternating divergent/ convergent thinking phases) was largely successful in reflecting the underlying design thinking model. For example, in the "Campus Space Design" project (one of the junior high units), we introduced a "design thinking toolkit" which provided students with various methods to diverge (brainstorm attributes) and converge (refine solutions); this toolkit concretely embodied the theoretical framework and was praised for helping students structure their thinking . In another project “Bionic Design,” students analyzed natural objects across six attribute dimensions (form, color, texture, structure, ability, meaning) and then applied those insights to invent new product ideas . This activity was highlighted as a strong example of linking theory to practice – it taught an abstract concept (learning from nature’s attributes) through a hands-on creative exercise. Additionally, most project themes were drawn from students’ everyday life contexts, such as school scenarios or familiar products, which made the learning experience more concrete and relatable . Teachers noted that this context relevance helped students quickly engage with problems, as they felt the problems were real and close to them. One area of critique in curriculum design was at the high school level, where the project topic was perhaps too broad and advanced given students’ lack of prior experience with independent research – the jump in difficulty was large, which caused some confusion . From this, we learned that scaffolding is crucial: when introducing novel, inquiry-based learning formats, especially to older students who are used to traditional instruction, I should ensure a gradual transition rather than an abrupt change. Overall, however, both teachers and experts felt that the curriculum design was well aligned with educational goals and provided a strong framework that guided practice with theory.

The second dimension, “Student Growth: Visible Outcomes,” was rated 4.1 out of 5 . This high score confirms that the curriculum led to observable improvements in student skills and outputs. As mentioned, students produced creative works in each project – for instance, physical prototypes like an “creative trash can” design made by primary students or an app interface designed by middle school students . Observers consistently reported that students were able to articulate their design ideas more fluently and apply design thinking methods independently by the end of the course. During the final presentations, many students demonstrated a grasp of the full cycle: they could explain how they researched a problem, brainstormed multiple ideas (attribute divergence), narrowed down and refined a chosen idea (attribute convergence), and tested or presented a prototype. Such behaviors indicated a development of metacognitive skills related to design thinking. The process-oriented growth was just as evident as the end products – for example, in one class I observed a student who initially struggled with ambiguity become one of the most active brainstormers in a later session, showing increased confidence in idea generation. Teachers also gave anecdotal evidence of student growth: some noted that students started to ask more questions in other classes and showed more creativity in regular art or science assignments, suggesting a transfer of design thinking skills beyond the project sessions. It was noted, however, that not every project achieved its full potential due to practical constraints. In the “Gamified Design” project (one of the primary Module B projects), students’ performance was comparatively weaker – this was attributed to insufficient time allocation and the complexity of the task . The gamification project introduced a fairly sophisticated framework (the “Octalysis” gamification model with eight psychological factors) and our schedule only allowed a couple of class periods for it. As a result, students spent a lot of time just grasping the concepts and had little time left to develop their creative game ideas, leading to rushed final outputs . This highlighted a need to balance depth vs. breadth – a simpler or longer-duration project might have yielded even more visible student growth. Despite this one case, the overall trend was that students visibly grew in their design thinking capabilities, which aligns with the significant test score improvements.

The third dimension evaluated was “Content: Comprehensibility (Difficulty)”, which had a moderate average rating of 3.6 out of 5 . This suggests that, while generally manageable, the curriculum content posed certain challenges for students’ understanding. Several factors contributed to the difficulty. For one, some projects required students to learn and use new technical tools that were outside their prior experience. For example, the “Object Attributes” project in Module A involved a 3D modeling software for students to create digital models of their designs . Many middle-school students had never done 3D computer modeling before, so initially they found it hard to pick up this skill during the project. We discovered that students without any prior exposure to 3D design needed substantial time just to learn the software basics, which ate into the time intended for creative design work. In future iterations, I recognized it would be helpful to either allocate more hours for tool-training or choose simpler prototyping methods for those groups. Another contributor to content complexity was the introduction of advanced design concepts and frameworks. As mentioned, the gamification project brought in eight categories of player motivation (mission, creativity, social connection, etc.) individually these concepts were not too difficult, but digesting all of them together was cognitively demanding for primary students . The volume of new information in such cases risked overwhelming some learners. These issues imply that the cognitive load of certain units was high. Experts reviewing the curriculum noted that the overall design thinking scaffold is strong, but some content might be “front-loaded” with too many new ideas at once. A proposed solution was to stretch those units over more sessions or integrate prerequisite skill training beforehand. In practice, however, we had to consider the limited time resources in real school schedules – not everything can be extended without bounds . In summary, the qualitative data on content difficulty indicate that while students were able to learn the material, certain projects required additional support or time. With adjustments (like better pacing, preparatory lessons on new tools, or simplifying complex frameworks), the comprehension aspect can be improved in future implementations.

The fourth dimension, “Materials: Supportiveness,” received an average rating of 4.0 out of 5 . This reflects that the teaching materials and resources provided were largely effective in supporting the course, though a few resource gaps were noted. I had prepared a comprehensive set of curricular materials (teacher guides, slides, student worksheets, etc.), and I also continuously introduced additional case examples and reference materials during the project implementation . Teachers reported that these resources were very helpful – for instance, seeing example design solutions from prior workshops helped them illustrate ideas to students. Furthermore, the schools themselves were fairly well-equipped: all participating schools had modern electronic classrooms, computer labs, and some experience with STEM or maker education, which meant they had tools like laptops, projectors, and even basic maker equipment that we could leverage . My research team also provided on-site support, essentially forming a “floating support crew” that visited each school regularly to help set up materials or troubleshoot issues (such as software installation or providing extra art supplies) . Because of this, most classes ran smoothly in terms of logistics and materials — lack of resources was generally not a barrier in our experiment. However, a couple of projects did pose unique material challenges. Both “Design Detective 1” (primary level) and “Design Detective 2” (junior level) projects required using the school’s real environment as a learning resource . In these projects, students had to observe and record aspects of their school (like taking photos of the cafeteria or hallways) and then analyze them. This meant the teachers had to do extra preparation: they needed to gather photographs and videos of the local environment for classroom discussion . In one case, a teacher spent significant time photographing various school scenarios prior to the lesson so that students could analyze those images. This was quite labor-intensive and highlighted that when curriculum activities rely on site-specific materials, the preparation workload on teachers increases. In future, I’ve considered providing a ready library of example images or guiding students to capture photos themselves as part of the activity (to distribute the work). Aside from such instances, the feedback on materials was that they were supportive and sufficient for achieving the lesson goals.

The fifth dimension, “Teaching Arrangement: Compatibility,” had an average rating of 3.6 out of 5 . This points to moderate compatibility of the design thinking course with the existing school schedules and infrastructure, with room for improvement. One compatibility issue was scheduling: in a typical school, lessons are 45 minutes long, but several design thinking activities really require longer blocks of time for optimal flow (for example, conducting user research and then immediately brainstorming solutions). We found that some project segments worked best when done in 2–4 consecutive class periods . However, arranging multiple periods back-to-back was challenging in the normal timetable structure. Some schools managed to allocate double periods for us (especially when doing hands-on making or final presentations), but this was an exception rather than the norm. This scheduling mismatch meant that in some cases we had to split an activity awkwardly across days, which disrupted continuity. It became evident that embedding design thinking into a traditional timetable might require more flexible scheduling or after-school workshops to maintain momentum. Another aspect of compatibility involves the needed technology and facilities. As noted, certain projects required computing devices, good internet connectivity for multiple devices, and even coordination with a 3D printing service for prototyping . During our experiment, we partnered with a professional 3D printing provider who helped print student designs this was a fortunate support, but one cannot assume every school has such access readily. Indeed, across our five schools, the availability of hardware and the robustness of IT infrastructure varied. Some schools had ample laptops for each student, while others had fewer devices or network issues. We had to adjust by, for example, using a projector demonstration instead of individual hands-on practice when devices were limited. This indicates that the curriculum needs flexible implementation plans depending on a school’s resource profile . For instance, if 3D modeling isn’t feasible, teachers could use physical clay modeling as an alternative. Additionally, a few projects demanded higher teacher expertise in design or technology (e.g. understanding CAD software or design theory) than what a typical teacher might have . We were lucky to have enthusiastic teachers, but some did express that they needed more training to feel comfortable with the content. In response, I see the necessity of comprehensive teacher training workshops before rolling out the curriculum at scale, to build teachers’ capacity in design thinking methods. In summary, while the pilot schools did manage to implement the course, ensuring compatibility with everyday teaching logistics remains a challenge. The course can be integrated, but scheduling adjustments, resource support, and teacher training are critical to improve its seamless fit in a normal school context.

The sixth and final qualitative dimension, “Teaching Content: Extensibility,” received the highest average rating of 4.5 out of 5 . This result indicates that the curriculum is highly flexible and extendable – a strong endorsement for its adaptability. Because the course is built around core design thinking principles (like focusing on human needs, iterating solutions, and abstract attribute analysis) rather than any specific subject matter, it was found that we could swap in different content topics or contexts without losing the educational value . For example, one of the projects, “Design Detective 1,” had a general goal of observing a real-world scenario and identifying design opportunities. In one school, students examined the lunch cafeteria experience, while in another school, students looked at the daily student pick-up process after school . These are very different scenarios, yet the underlying thinking skills practiced were the same: students learned to observe carefully, document issues, and propose improvements. The observers and teachers noted that the choice of scenario could be flexibly tailored to each school’s needs or a student’s interest, and the project still worked because it was scaffolded by the attribute-based thinking approach. Similarly, in the high school "Senior Product Design" project, one school's students chose to design aids for the elderly, whereas another group might have chosen a different user group – the content could change, but the process (empathize, define, ideate, prototype) remained constant. This suggests the curriculum can be expanded or adapted to numerous themes (healthcare, environment, campus life, etc.) while maintaining its integrity. Experts at the review commented that this extensibility makes the curriculum suitable as a framework that schools could adopt and then plug in context-specific projects . In practice, this means a school could use the attribute-based design thinking model to address local problems of their choosing – it's not a one-size-for-all content, but a flexible model. The high extensibility score (4.5/5) thus reflects that stakeholders found the approach broadly applicable and not overly tied to any narrow content.

Additional Qualitative Insights – Teacher and Expert Feedback: Beyond the formal dimension ratings, it's worth highlighting some insights from teacher feedback and the expert evaluation. Teachers were generally enthusiastic about the pedagogical shift but also candid about the challenges it posed for them. One veteran teacher noted that a problem-driven, project-based design class is "a big challenge for teachers" because unlike a typical lesson, "you don't know where the problem will go; even if you spot a problem, you might not immediately know the solution" . This underscores a key aspect of design thinking education: it requires teachers to embrace uncertainty and facilitate learning without always having a right answer in advance. Over the course of the experiment, teachers became more comfortable with this role – acting as guides and co-creators rather than lecturers. We saw many teachers grow in their own mindsets, becoming more open to student-driven inquiry. For instance, at one school, teachers adopted an "exploratory learning" stance: "As teachers we intervened as little as possible in students' thinking process, only guiding them at crucial points," one teacher explained . This hands-off facilitation was a departure from their usual teaching style, and by practicing it, teachers learned to trust students more and observe their creative reasoning. Teachers also contributed greatly to improving the curriculum on the fly. Several teachers came up with creative adaptations or supplementary materials that enhanced the lessons. For example, a teacher at Bao'ta Experimental School added a wonderfully apt introductory case to the "Attributes of Objects" lesson – she asked students to "find a cat in an owl" (using visual analogy) as a fun way to kick off attribute analysis, which the students loved . In another case, a teacher provided extra context on "fast thinking vs slow thinking" when students questioned the purpose of a particular exercise . These teacher-driven innovations were shared in our teacher collaboration group chat and benefited other classes as well. Overall, teacher feedback affirmed that the design thinking curriculum was worthwhile and impactful, while also highlighting the need for support (training, resources) to execute it well. Many teachers remarked that despite the workload, they found joy in seeing their students evolve and would want to continue teaching such courses.

Finally, the expert panel review provided an external perspective on the results. After the completion of the curriculum modules, I hosted a provincial design education review meeting with experts in design, education, and curriculum research (from universities and the Department of Education), as well as principals and lead teachers from the experimental schools . During this meeting, I presented the curriculum framework, student work exhibits, and summarized outcomes (both quantitative and qualitative). The experts' consensus was encouraging: they concluded that "design education" in these pilot schools had achieved initial success on multiple levels – student learning, teacher development, and curriculum model – and showed great promise . One university professor who had been deeply involved described our design thinking curriculum as "an independent system of courses" with its own distinct form, yet one that remains compatible with and extensible to traditional education . In other words, they saw it not as a one-off experiment but as a reproducible program that could stand alongside other subjects. The panel of experts strongly supported the idea of integrating design thinking education across grade levels. They stressed that a top-down vision is needed to embed such innovative curricula into the education system, with a progression from primary through high school . An engineering education expert on the panel noted that "we need to introduce engineering and design experiences gradually in elementary and junior high, because learning by doing is so important", highlighting how the hands-on aspect of our course aligns with developing practical skills early . A design scholar on the panel spoke about the unique value of design in K-12, saying that "design allows thinking to be visualized… the core of design thinking is the human element", reinforcing our course's human-centered approach . An education professor remarked on the broader context: as education reforms shift from pure knowledge transmission to competency development, courses like ours encourage students "to think like experts" and balance content learning with the cultivation of transferable high-level thinking skills . This aligns perfectly with the goals of design thinking education. In summary, the expert review validated my findings: the attribute-based design thinking curriculum was seen as innovative, effective, and aligned with the future direction of education. The experts encouraged scaling up this program and continuing research to refine it. They also echoed some practical considerations, such as providing sustained support and policy backing to integrate design thinking into the formal curriculum.

In conclusion, the results of this study demonstrate that the attribute-centered design thinking curriculum had a significant positive impact on students' creative thinking and problem-solving abilities, as evidenced by both quantitative gains in creativity and rich qualitative feedback. I observed students become more open-minded, resourceful, and reflective – hallmarks of design thinking – over the course of the intervention.

Teachers and external evaluators likewise noted these improvements and contributed insights to further enhance the curriculum. The data also shed light on challenges, including ensuring content is age-appropriate, adjusting to school logistical constraints, and supporting teachers through training and resources. These findings will guide future iterations of the curriculum. Overall, from a first-person perspective as the researcher and practitioner, I found that implementing a design thinking program in basic education is not only feasible but highly beneficial. The study's mixed-method evidence supports that with thoughtful design and collaboration, we can cultivate young students' design thinking and creativity in a systematic way, ultimately fostering the innovative talents needed in the new era. The experience and results from this research serve as a foundation for expanding design thinking pedagogy to more schools and inform best practices for such interdisciplinary, skills-focused curricula in the future.

5 RECONSTRUCTION OF DESIGN THINKING MODEL BASED ON ATTRIBUTE CONSTRUCTION

5.1 Attribute and the Hierarchy of Cognition

Attribute is a general term that encompasses the properties of objects (such as color, smell, use, material, etc.) and the relationships between objects (such as size, spouse, friend, distance, contradiction, etc.). It represents the abstract portrayal of a cognitive object. Objects (or existence) are composed of attributes, and attributes exist as dependent on objects [6]. According to whether the attribute is unique to a particular type of object, attributes can be classified into unique attributes and common attributes. Furthermore, based on whether the attribute has a decisive significance to the object, attributes are also classified into essential attributes (The essential attribute) and non-essential attributes. Concepts are forms of thinking that reflect the objects of thought and their essential attributes. Understanding the definition and classification of attributes helps us re-examine the concept of design thinking. Attributes are the tools through which we recognize and grasp the essence of things, but simply listing attributes is not enough to reach the essence of objects. Unified value theory suggests that objects consist of four basic levels: attributes, wholeness, regularity, and systematics.

- **Attributes** represent the way matter exists, as well as the external relations between different objects. For example, the attributes of water include being colorless, tasteless, and having fluidity. All attributes belong to the category of existence.
- **Wholeness** refers to the integration of all the attributes of an object, extending the concept of attributes. For example, the attributes of water—being colorless and tasteless—constitute the "whole" of water.
- **Regularity** refers to the interrelationships between the attributes of the whole. These include the temporal, spatial, and causal relationships between objects, which are extensions of their wholeness.
- **Systematicity** represents a higher-level unity and interconnection, an extension of regularity. The higher the level of an object, the more enriched its attribute construction becomes, resulting in greater diversity, dynamics, and complexity.

The levels of objects, consciousness, and propositions together form the hierarchical structure of cognition. Since consciousness is the subjective reflection of objects by the human brain, it can also be divided into four levels: attributes, wholeness, regularity, and systematicity. Similarly, propositions can be divided into levels: impression, concept, law, and theory.

5.2 Attribute Thinking Unit

Based on the cognitive hierarchy and previous valuable explorations of thinking patterns, we propose the model of attribute thinking units (Figure 1). The model uses time for the horizontal axis and complexity for the vertical axis, describing the process of change in attribute complexity over time. Built upon the divergence and convergence of thinking, the model constitutes the smallest cognitive and understandable unit of attribute construction [7], completing the independent closed loop of attribute construction.

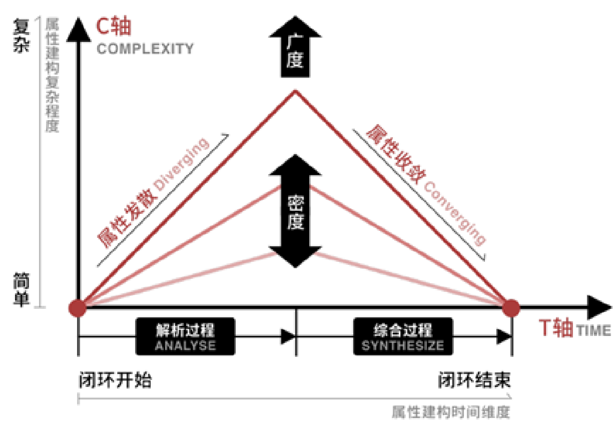

Figure 1. The Model of Attribute Thinking Units

5.2.1 The Time Dimension of Attribute Construction

In the attribute thinking unit, the horizontal axis represents the time dimension of thinking. The time dimension demonstrates the dynamic, procedural, generative, and practical nature of thinking, reflecting the inherent movement and change laws of thought. Each smallest unit of attribute construction contains both an analysis and a synthesis phase. In the analysis phase, understanding and grasping of attributes are divergent; in the synthesis phase, these understandings become convergent.

Analysis and Synthesis. Analysis and synthesis are two complementary stages in the thinking process. Analysis refers to deeply examining the problem, breaking it down into smaller issues or attributes for separate understanding and resolution. Synthesis, on the other hand, involves recombining these smaller issues or attributes to form a complete understanding or solution. Each synthesis is built upon the results of analysis, and every analysis requires a synthesis to make value judgments and derive new conclusions. In Figure 1, although analysis and synthesis occupy equal lengths on the time axis, this is an idealized representation and does not have strict numerical significance. The sequence of analysis and synthesis is chronological, but the specific duration of each phase may vary depending on the practical context.

Divergence and Convergence. Divergence and convergence in attribute construction are reflected on the time-complexity plane. The purpose of introducing the attribute concept is not to challenge the laws of thinking divergence or convergence, but to delve deeper into the intrinsic, implicit, and substantial principles of cognitive change based on established conclusions. Divergence and convergence are represented by the slope of the time-complexity line. In Figure 1, the positive or negative slope reflects the overall tendency of thinking: a positive slope indicates divergence, while a negative slope indicates convergence. It is important to note that we do not compare the absolute values of the slopes, as the absolute value does not have strict numerical significance in this paper.

5.2.2 The Complexity Dimension of Attribute Construction

In the attribute thinking unit, the vertical axis represents the complexity dimension of thinking. At each specific moment in time, the state of things within the entire problem-goal system determines their relative position on the vertical axis. In the analysis phase, the overall complexity of attributes increases as time progresses; in the synthesis phase, the complexity of attributes decreases until it reaches a stage of aggregation. As with the horizontal axis, the complexity dimension does not carry mathematical significance and serves only as an idealized graphical representation. Complexity can be further broken down into two sub-dimensions: breadth and density.

The Breadth of Attribute Construction. The breadth of attribute construction represents the cognitive hierarchy of attributes and reflects the qualitative change in cognition and the height of thinking. The levels of breadth, from low to high, include independence, wholeness, regularity, and systematics. In Figure 1, breadth corresponds to the outermost time-complexity line.

The Density of Attribute Construction. The density of attribute construction refers to the number of branching paths involved in constructing relationships and the number of related cognitive objects. It can also be described as the "diversification within the cognitive scope", reflecting the quantitative change in cognition. The levels of density, from low to high, range from a single cognitive object to complex cognitive objects. In Figure 1, density corresponds to all the inner time-complexity lines, representing the number of internal attribute thinking threads.

In practice, there is often a positive correlation between the breadth and density of attribute construction. Problems with higher breadth usually require higher density to support the construction of complex attribute relationships. Additionally, when designing complex systems, it is necessary not only to consider the individual components of the system (breadth) but also the relationships between these components (density) to ensure the system's integrity and coherence.

5.3 Reconstruction of Design Thinking Model

In Section 3.2, we clarified the basic units of cognitive construction, as well as key elements such as the time dimension, complexity dimension, analysis and synthesis, divergence and convergence, breadth and density, through a visual approach. By integrating attribute thinking units and the general principles of the full design process as outlined in the Double Diamond model, we propose the attribute-based design thinking model shown in Figure 2. From a macro perspective, problem discovery and solution development correspond to the attribute divergence stage, while problem definition and solution delivery correspond to the attribute convergence stage. Problem analysis and definition constitute the first closed loop of divergence-convergence, while idea generation and solution delivery form the second closed loop. From the micro perspective of attribute thinking units, each macro closed loop can be further divided into countless micro-closed loops. The divergence and convergence of attributes within the macro closed loop represent the overall trajectory of thinking. Based on the attribute-based design thinking model, during the design practice process, we can predict the complexity of the design target's attributes after determining the current design phase. This allows us to match design thinking tools that align with the attribute characteristics, and effectively support the advancement of the design thinking process.

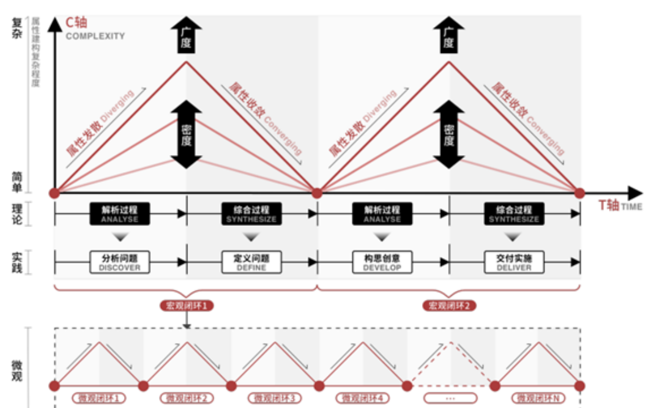

Figure 2. The Design Thinking Model Based on Attribute Construction

6 SUGGESTIONS FOR DESIGN THINKING CURRICULUM DEVELOPMENT BASED ON ATTRIBUTE CONSTRUCTION

6.1 Curriculum Orientation

For the basic education stage, the design thinking curriculum should be positioned as an extension course that integrates comprehensive design experiences and design practices. Design education has started relatively late in China's basic education system. Currently, although design education courses have gained a relatively independent curricular form, the mainstream approach is still to integrate these courses into the daily teaching process of primary and secondary schools in the form of elective extension courses, such as labor and technology, practical courses, general technology, science, STEAM, and PBL project-based school curricula. While these courses may vary in name and form, they all require innovation, creativity, and design thinking. Therefore, the design curriculum can be implemented by integrating it with existing course content, maintaining a certain level of flexibility and adaptability. In addition, adopting a combination of compulsory and elective courses can help form a flexible curriculum plan, making it easier for schools to implement and adapt the curriculum according to their own circumstances.

6.2 Curriculum Gradient Design Guided by the Complexity Dimension

The inherent cognitive gradient construction of the design curriculum includes two aspects: the breadth and the density of attribute construction. The gradient construction of breadth progresses in difficulty according to the sequence of independence, holism, regularity, and systematization. The gradient construction of density gradually transitions from the cognition of a single object to the cognition of complex systems. The mapping of cognitive gradients onto the curriculum gradient is reflected in three aspects: design topics, classroom content density, and design tools. In the practical construction of the gradient, due to the continuity of cognitive development and the complexity of real-world contexts, there is no absolute hierarchical division between courses; instead, there are relative levels of difficulty.

6.2.1 Selection of Design Topics

The selection of design topics should gradually transition from the exploration of simple problems to the study of more complex ones [6], ensuring that the authenticity of the problems, their reducibility in classroom interaction, and their abstraction increase progressively. According to Piaget's theory of cognitive development in children, cognitive development is a constructive process achieved through continuous interaction with the environment. Therefore, the complexity of the design topics should align with the students' cognitive development stages, ensuring that students can progressively construct design thinking through practice.

Specifically, at the elementary school stage, students are in the concrete operational stage and need to use concrete perception and manipulation to understand abstract concepts. The curriculum design at this stage should guide students to observe and understand natural and man-made objects from different perspectives through various project themes, fostering their ability to discover new meanings and values through the analysis of attributes in everyday objects and behaviors, thus cultivating the ability to see the extraordinary in the ordinary. At the middle school stage, students are in the formal operational stage, able to transcend the influence of reality and focus on abstract propositions and engage in hypothetical-deductive reasoning processes.

Therefore, the curriculum for junior and senior high school should focus on constructing systematic problem-solving tasks, cultivating the ability to investigate complex attribute-based issues, and enhancing students' system thinking, innovative design, and comprehensive application skills.

6.2.2 Setting of Curriculum Content Density

The design of classroom content density should gradually transition from individual attribute divergence or convergence components to a complete design thinking problem-solving process, encompassing the construction of multiple attribute thinking units.

For example, the curriculum at the elementary school stage can begin with the holism of attributes, breaking down simple objects or simplified complex scenarios to perceive the independence of attributes and attempt to deduce patterns between attributes, with systematization introduced as an extension requirement. In the middle school stage, the curriculum should require a deeper analysis of the attributes of a single cognitive object, particularly focusing on the regularity and systematization of attributes. This can involve introducing complex cognitive objects such as commercial products or public spaces. The curriculum at the high school stage should adopt a complete design thinking process, guiding students to establish a systematic consideration of the relationships between business, product, and user needs.

6.2.3 Supply of Design Thinking Tools

The selection of design thinking tools should transition from training on a single designated design thinking tool to the selection and application of multiple design thinking tools. This selection should follow the principles of tool selection and application in design thinking, gradually introducing diversified design thinking tools based on students' cognitive abilities and course objectives to enhance their comprehensive application abilities.

For example, in elementary school, simple observation and recording tools such as the AEIOU observation chart can be used to guide students in perception and analysis. In middle school, design thinking tools like empathy maps can be introduced to help students conduct in-depth user research and needs analysis. In high school, more diverse design thinking tools, such as 3D modeling software and user testing tools, can be introduced to help students with complex design and validation tasks.

6.3 Curriculum Procedure Design Guided by the Time Dimension

According to the time dimension of cognitive development, the curriculum design for design thinking education should be based on project-based teaching and reflect the cyclical alternation of two stages: attribute divergence and attribute convergence, which correspond to the iterative construction of the attribute thinking unit. Each analysis and synthesis stage should correspond to a specific course component, ensuring that students clearly understand the tasks and objectives of each stage, thereby ensuring the effectiveness of design thinking training. For example, during the "attribute divergence" stage, activities such as brainstorming and creative workshops can be designed to stimulate students' innovative thinking; during the "attribute convergence" stage, activities such as prototype development and user testing can be used to help students validate and refine their solutions. The time allocation for each component should be adjusted according to actual teaching needs to ensure students have sufficient time for deep thinking and practice.

If the design cycle is too long, in teaching practice, it may be necessary to divide a complete design project into multiple design lessons based on course duration limits and the time requirements of each component. In such cases, the specific objectives of each design project should be clarified at the beginning of the course, and time should be allocated reasonably according to the goals. For example, for a four-week design project, the first two weeks can be set for the "attribute divergence" stage, while the last two weeks can focus on the "attribute convergence" stage. During the "attribute divergence" stage, students are encouraged to generate as many ideas and solutions as possible, whereas in the "attribute convergence" stage, the focus is on evaluating and selecting the most effective solutions.

7 CONCLUSION

This paper delves into the two core propositions of "What is design thinking" and "How to cultivate design thinking in the basic education stage", and conducts a systematic study of the pathways for cultivating design thinking from a theoretical perspective. The study starts from the theoretical connotations of design thinking and innovatively introduces the concept of attributes, constructing an attribute-based cognitive unit and proposing a design thinking model grounded in attribute construction. In combination with the current state of design education practices in China's basic education stage, this paper offers a series of strategic recommendations for curriculum positioning, curriculum gradient design, and course process design, based on the time and complexity dimensions of attribute construction.

Overall, this paper provides a new perspective and methodology for cultivating design thinking in the basic education stage. It is conducive to advancing design thinking curriculum research, development, and practice, further deepening the exploration of the essence of thinking and improving the overall planning of the development path of design thinking. In the future, with the ongoing deepening of China's educational reforms, design thinking is expected to see further application and promotion in basic education, and the effectiveness and applicability of the findings in this paper are likely to be validated by more empirical research.

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