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A Lesson Study on the Design and Implementation of Maker Education Courses in Primary Teacher Education: An Interdisciplinary Perspective

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ABSTRACT

Against the background of ongoing basic education curriculum reform, coupled with the inherent limitations of traditional teacher teaching modes and the prominent dilemmas in cultivating high-quality maker-oriented pre-service teachers, this study carries out empirical lesson study research grounded in the maker learning model. By clarifying the core connotation of the "maker" and drawing on the theoretical framework of the self-efficacy theory, it explores feasible pathways to integrate maker thinking cultivation into classroom teaching activity design and strives to implement the integrated teaching idea into formal primary pre-service teacher education classrooms. Taking the undergraduate elective course Practice of Maker and Intelligent Manufacturing Tools offered at a comprehensive normal university as a particular research case, this paper elaborated in detail the overall design, practical arrangement and specific implementation process of curriculum maker activities. Data were retrieved from student learning portfolios, classroom video recordings, and representative student practical works. The results indicate that the course design can effectively stimulate pre-service teachers' learning initiative and practical participation enthusiasm, and fully embodies the practicality, openness and innovation characteristics of modern maker education. This research offers valuable theoretical reference for the in-depth integration of maker education into pre-service teacher education systems, and bears important practical implications for fostering outstanding primary teachers adapted to the new demands of educational modernization and innovative talent training.

Keywords: Maker Education; Teacher Education; Maker Thinking; Curriculum and Activity Design and Implementation

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1. Introduction

Problems in social life are complex and keep changing. Single-discipline knowledge is insufficient to help teachers understand the constantly emerging complex phenomena, and real-world problems often require the integration of multidisciplinary knowledge to be effectively resolved. Maker education focuses on interdisciplinary integration, bringing together science, art, engineering, and technology. Scientific knowledge describes the world objectively. Artistic knowledge helps teachers understand the world in a divergent way. Engineering knowledge materializes and changes the world through physical creation. Technological knowledge standardizes and connects the world [1]. By integrating resources from society, schools, enterprises, and professional fields and by creating suitable teaching contexts, maker education achieves a process of comprehensive learning that promotes students' STEM competencies and whole-person development [2–4] . It has become a strong driver of teaching reform [5].

In this study, maker education not only integrates interdisciplinary learning but also pays attention to creative products that take physical form. Beyond making tangible objects, cultivating students' maker thinking is also important, which is always neglected [6]. In this way, students achieve holistic development as they discover and solve problems. The implementation of maker education models in primary and secondary schools depends on enhancing the maker literacy of teachers and providing them with proper guidance. However, in recent years, there are prominent issues such as relatively outdated teaching content and methods in maker courses, as well as a shortage of maker-oriented teachers [7,8]. To address these challenges, it is essential to significantly increase both the quantity and quality of maker teacher training. The goal of cultivating maker-oriented teachers is to foster the development of their maker mindset, establish their identity as maker-oriented educators, transform traditional teaching methods, enhance their ability to integrate interdisciplinary knowledge, solve problems in real-world contexts, and develop a high-quality teaching workforce capable of meeting the demands of modern education.

To achieve the above research objectives against the backdrop of basic education reform and the innovative transformation of pre-service teacher education, this study explores and attempts to systematically address two pivotal research questions regarding the professional growth and cultivation of maker-oriented teachers: (1) How should normal universities formulate scientific and rational approaches to systematically develop competent maker-oriented teachers? (2) What key professional competencies and comprehensive literacy should qualified maker-oriented teachers inherently possess to meet the evolving demands of contemporary basic education? Based on the theoretical connotation and practical framework of the maker-oriented learning model, this study centers on a specially designed and delivered elective course for pre-service teacher education students entitled Practice of Maker and Intelligent Manufacturing Tools. Following the complete process of curriculum design, classroom teaching implementation and instructional arrangement, the research collects students' learning reflections and feedback after course participation. On this basis, the researchers conduct in-depth teaching reflection on the whole teaching process, summarize practical experience in maker education teaching, analyze existing shortcomings in curriculum design and classroom practice, and further propose concrete, targeted and feasible implementation strategies for the sustainable cultivation of maker-oriented teachers in normal university settings.

2. Literature Review

Scholarly research on maker education primarily focuses on students from preschool to senior high school [9,10]. Prior literature explores how maker education reshapes traditional instruction and nurtures students' problem-solving skills, maker mindset, and maker literacy [11–13]. In well-designed school makerspaces, students combine traditional tools and modern technologies. They enhance creativity ability, strengthen hands-on skills, cooperate with peers, and turn abstract ideas into physical artifacts. To cultivate and sustain such student-centered maker learning, academic discussions expand to teachers' professional development [14–16] and makerspace support [17,18]. Schools are required to bear the responsibility to establish well-established makerspaces and well-prepared teachers to deliver immersive maker learning experiences for students [19]. However, a literature review by the authors identifies an obvious research gap. Scholars have thoroughly examined students and frontline in-service teachers [20], yet few studies investigate maker literacy among pre-service teachers. If they master maker teaching skills and competencies during training while within university, there may be possibilities that they better design and implement maker oriented courses after graduation and at work.

The integration of maker education into teacher education has evolved from theoretical conceptualization to systematic practice, rooted in Dewey's learning-by-doing and Papert's constructionism [21]. Following the first Maker Faire in 2006, maker education gained traction for fostering creativity and interdisciplinary competence, yet widespread implementation revealed a critical shortage of teacher readiness, with approximately 40% of educators reporting inadequate preparation for maker-centered instruction [22]. Early training efforts remained fragmented and skill-oriented, focusing on basic tool use rather than holistic pedagogical integration, reflecting a global gap in systematic teacher preparation frameworks [14,21,23].

Between 2019 and 2025, empirical research on maker education in teacher education expanded rapidly, shifting toward pre-service teacher development, immersive experiential learning, and interdisciplinary design [21]. Representative initiatives, such as the NSF-funded T.I.M.E. for STEM projects, embedded makerspace pedagogy into pre-service elementary teacher curricula, emphasizing interdisciplinary lesson design and hands-on practice [24]. Despite this progress, most programs combined theoretical knowledge with practical skills but failed to prioritize the specific competencies and maker mindset required for effective interdisciplinary maker instruction, leaving a persistent gap in context-specific, full-process training models [21]. According to the review study mentioned above, with regard to the geographical distribution of the published studies, it is notable that approximately half were conducted in the United States and Canada, and Global South countries (e.g., China) should also investigate how to equip teachers with Maker mindset and activity design ability. Regarding the appropriate integration of maker practices into the curriculum, a lack of research was identified [25], particularly in the area of providing pre-service teachers with the training needed to incorporate maker principles in their classrooms.

In China, integrating full-process interdisciplinary maker education activities into university-based primary teacher education curricula is therefore both necessary and urgent. Aligning with national goals of fostering innovation and holistic development, such a design addresses the global teacher readiness deficit, bridges the theory-practice divide in traditional Chinese teacher education, and responds to the interdisciplinary nature of modern primary education [21,24,26]. Furthermore, it fills the research void of localized maker education frameworks tailored to China's educational context, ensuring that pre-service teachers develop the capacity to design, implement, and evaluate interdisciplinary maker activities in real primary classrooms.

A search was conducted in the China Academic Journals database on CNKI (a Chinese database). Since discussions on maker education began to emerge in 2013, a total of 6,524 papers have been published on the topic of maker education. Among these, 657 papers focus on primary and secondary education from the perspective of student learning. However, only 39 papers use the term "maker teacher" as their titles. Research on the cultivation of maker teachers is mostly situated in in-service teachers and focuses on science and engineering disciplines in low socioeconomic areas [27]. These studies often discuss apprenticeship models and dual teacher systems in vocational colleges or other higher education spaces, looking at teacher professional development and student training pathways [28]. Very little attention has been given to how pre-service teachers trained for primary and secondary schools can become maker teachers [26]. This theme is rarely addressed in the existing literature.

Directly searching for "maker teacher cultivation" in the CNKI database yields even fewer results. In the past three years, existing studies on primary education student teachers have consistently shown that pre-service teachers generally exhibit vague and superficial understanding, and insufficient value recognition of maker education concepts. Most student teachers simply equate maker education with manual production, robot building, or information technology skill training, failing to grasp its core connotations including innovative thinking, practical creation, interdisciplinary integration, learning by doing, and competency-oriented education. Jin and Li pointed out that long-term training in traditional subject-based teaching has left student teachers with a weak awareness of interdisciplinary integration [29]. They lack a clear understanding of the internal relationship between maker education and primary general education as well as comprehensive practical activities, and tend to fall into the misconception of valuing skills over thinking and emphasizing results over processes.

Li Biwu pointed out that maker education is a highly comprehensive and innovative form of education [30]. In the process of training primary and secondary school teachers, the lack of maker education teachers is a real problem because maker education requires specific maker competencies such as handling equipment and mastering specialized knowledge. He thus explored ways to cultivate maker teachers from the perspective of teacher training [30]. As for theoretical studies on the cultivation of maker teachers, only Wu Yanru and Tang Yaohui started from the lens of technology and proposed the thinking abilities and thinking dispositions that maker teachers need to possess [31]. Whether for meeting practical needs or enriching theoretical foundations, this paper offers a valuable answer to the question of how maker education can be integrated into the pre-service teacher education system.

2.1. Maker and Maker Learning

To briefly summarize, the term "maker" originates from the English word "Maker" and refers to people who, driven by interest and passion, strive to turn various creative ideas into reality [32]. A maker-oriented teacher is a modern educator who centers on students' interests and guides them through hands-on creation activities in real-world problem scenarios to cultivate their maker mindset.

Different disciplines—such as philosophy, sociology, and education—have varying definitions of learning. However, these definitions share an intrinsic connection, viewing learning as an activity that brings about physical and mental changes in individuals through social interaction and practical experience. A person learns effectively only when he/she connects learning with personal interests, interpersonal relationships, and potential opportunities [33]. As a key initiator of the global maker movement, Hatch argued that maker learning emphasizes hands-on experiential creation rather than rote knowledge transmission, enabling learners to develop innovative cognition and practical competencies through participatory making activities [34]. Martinez and Stager highlighted that effective maker learning relies on student-centered collaborative inquiry and interdisciplinary situational tasks, rather than a simple accumulation of technical equipment, which helps stimulate learners' creative problem-solving potential [35].

In this study, maker learning specifically refers to a new learning model centered on maker projects based on real-world problem scenarios. Within dedicated maker learning spaces, by effectively utilizing available resources (computers, laser cutters, Laser-Maker software, birch plywood, and technical processing techniques), it involves continuous knowledge construction and application, ultimately fostering maker thinking, updating perspectives on learning and teaching, and achieving holistic education.

2.2. Maker Learning Models

Zhong and Sun argue that models serve as intermediaries between theory and practice, characterized by typicality, imitativeness, and mediating functions [36]. A learning model, on the other hand, is a stable framework of learning activities constructed on the basis of a specific theory to achieve learning objectives. This study primarily examines four traditional teaching models.

The first traditional learning model is the lecture-based model. The "lecture-based model" proposed by Comenius in The Great Didactic in 1967 laid the foundation for teacher-centered classroom instruction [37]. The second one is the self-directed learning model. In 1977, American psychologist Bandura proposed the theory of self-efficacy, noting that a sense of self-efficacy influences learning initiative, with students organizing their studies independently based on their own goals [38]. The third one is the cooperative learning model. From the late 1970s to the early 1980s, American educationalist Slavin conducted in-depth research and proposed related strategies, in which students work in groups to complete tasks, collaborating with one another to achieve goals and cultivate teamwork and communication skills [39]. The last one is the inquiry-based learning model. In 1910, John Dewey proposed the "learning by doing" theory, which is problem-driven and emphasizes students acquiring knowledge through hands-on practice [40]. Students gather information, analyze, and verify around a problem, thereby enhancing their innovation and problem-solving abilities.

Compared to the traditional models, maker learning model has a wide variety of new emphases [41]. Anderson pointed out that maker education can break traditional disciplinary boundaries, integrate emerging information technologies with daily teaching, and serve as an effective approach to cultivating innovative interdisciplinary talents [42]. First, regarding learning objectives, the maker learning model centers on innovation and practice, striving to transform students' creativity into tangible outcomes that solve real-life problems, heavily influenced by John Dewey's pragmatism [43]. Second, from the perspective of learning process, the autonomy and openness of maker learning are far beyond traditional models. In maker learning, students independently control the whole process from the initial creative idea to design, material selection, production, debugging, and especially emphasize the integration of interdisciplinary knowledge. For example, the production of intelligent robots requires the comprehensive use of multidisciplinary knowledge such as physics, electronics and programming, which is difficult to achieve in traditional models. Third, in terms of learning outcomes, maker learning is characterized by its distinct tangibility and practicality. Maker learning produces concrete physical artifacts, heavily influenced by Seymour Papert's constructionist [44].

3. Theoretical Framework

Drawing on Bandura's self-efficacy theory, this study anchors on the premise that students' perceived competence critically shapes their engagement with innovative and interdisciplinary pedagogies [45]. Self-efficacy refers to context-specific beliefs about one's capacity to organize and execute desired actions, influencing task selection, effort investment, persistence, and responses to failure [45]. Recent scholarship underscores that students' self-efficacy is not static but dynamically constructed through hands-on experience, social feedback, and reflective practice [46,47]. In maker education contexts, when instruction is open-ended, collaborative, and cross-curricular, self-efficacy becomes especially pivotal, as it determines whether students embrace complexity or avoid instructional uncertainty [48].

Maker education demands interdisciplinary design, iterative making, and student-centered facilitation. Many pre-service primary teachers may lack these competencies, often triggering anxiety and avoidance in future classrooms [21,24]. Empirical evidence confirms that immersive, full-process maker activities serve as powerful sources of mastery experience, enabling pre-service teachers to build tangible evidence of their ability to design and deliver integrated lessons [48]. Frontiers research further highlights that scaffolded maker interventions, rather than unstructured exploration, significantly enhance self-efficacy by balancing challenge with support [49]. Such experiences directly address the global gap in teacher readiness for interdisciplinary, technology-enhanced instruction [21].

The relationship between self-efficacy and interdisciplinary maker education is reciprocal and reinforcing. Well-designed maker curricula foster students' efficacy by providing authentic, competence-building experiences that align with real-world primary classroom demands [48]. Conversely, high self-efficacy empowers students to navigate ambiguity, sustain motivation amid setbacks, and adopt innovative practices [46,47]. This dynamic creates a positive cycle: belief in capability drives engagement, while successful engagement strengthens efficacy, laying a robust foundation for sustained integration of maker education into Chinese primary teacher education and classroom practice.

4. Methodology

This study adopts a qualitative lesson study methodology for curriculum exploration [50]. This method suits in-depth, context-based research on instructional design and classroom practice. It differs from quantitative studies that require large sample sizes for statistical inference. Lesson study focuses on detailed observation of real teaching scenarios and intensive instructional reflection. It effectively reveals practical mechanisms and potential challenges of curriculum implementation. Unlike quantitative research that relies on large samples for statistical inference, lesson study focuses on fine-grained observation of authentic teaching practices. It supports iterative reflection on real curriculum delivery and helps teachers identify practical instructional mechanisms and contextual challenges.

The research participants were 10 pre-service primary teachers taking the elective course Practice of Maker and Intelligent Manufacturing Tools. All participants attended classes regularly and finished all practical learning tasks across the nine-week curriculum. Though the sample size is small, every student maintained full and continuous participation. Their complete learning process generates sufficient longitudinal data to support rigorous qualitative analysis and reliable contextual interpretation. Notably, the curriculum design adopted in this study was co-developed with a professor with extensive research expertise in maker education. The collaborative design process ensured the rationality, interdisciplinary nature and practical feasibility of the course framework.

4.1. Maker Education Course Design for Lesson Study

This course is an elective for the Elementary Education program. It is interdisciplinary in nature and represents a new type of curriculum dedicated to bridging educational theory with embodied learning practices. The term "Maker" refers to anyone who, driven by interest and necessity, strives to turn creative ideas into reality. A passion for modern technology, a love for hands-on practice, and a willingness to collaborate and share are the distinctive hallmarks of a maker. Based on the "Making" and "Interdisciplinary Learning" principles of maker education, this course integrates six typical maker thinking qualities with laser fabrication projects. It primarily covers three instructional components: first, maker education philosophy and maker fabrication tools; second, six types of Maker thinking and six maker fabrication projects; and third, project presentations and learning reflections.

Guided by the maker learning model described above, which features innovation and practice, autonomy and openness, and tangibility and practicality, this course follows a specific organizational structure, and activity design comprises four fundamental elements: activity objectives, content of activity, activity organization, and activity evaluation [51]. In this course, instructors have established four learning objectives: acquiring knowledge of making things, cultivating a maker mindset, conducting comprehensive problem analysis, and defining solutions. Students integrate tasks centered on diverse, real-life scenarios and follow the "teach-learn-create" sequence of course activities to complete iterative tasks (Version 1.0 and Version 2.0) and engage in reflection. The course content guides pre-service teachers to engage in interactions between people and objects, fostering the maker learner's ability to "create things" (understanding and changing the world) and "construct oneself" (understanding and changing oneself) [52].

4.1.1. Course Objectives

The maker-oriented course development and design model is shown in **Figure 1**.

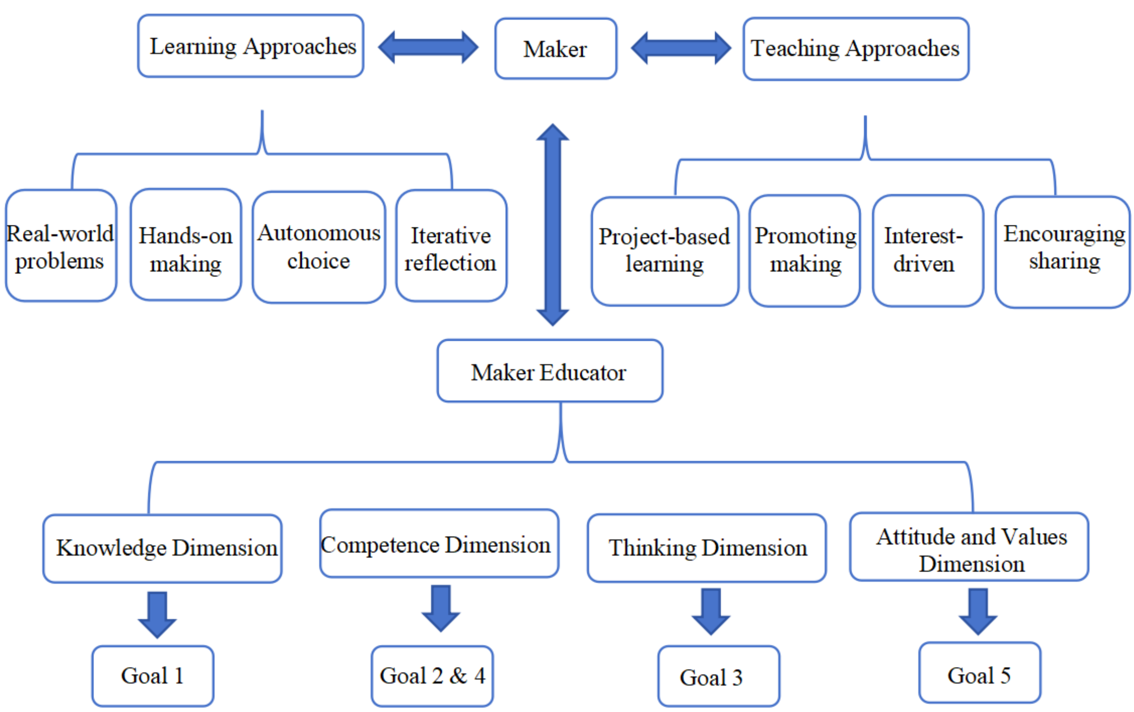

Figure 1. Course Objectives Design of Maker Education Courses.

The objectives are as follows:

- Course Objective 1: Master foundational maker tools and fabrication techniques. Understand the authentic maker journey from ideation to design, fabrication, and iteration, and bring creative ideas to life.
- Course Objective 2: Develop the ability to identify, analyze, and solve problems; respect labor and facts; and cultivate product awareness and a craftsman's spirit during the creation process.
- Course Objective 3: Understand the essence and characteristics of maker education; master the meanings, values, and cultivation methods of the six maker mindsets: growth mindset, design mindset, innovative mindset, critical mindset, collaborative mindset, and caring mindset.
- Course Objective 4: Improve the ability of teamwork and innovation and creativity, form a healthy personality that is good at innovation, diligent in sharing, confident and optimistic, and lay the foundation for adapting to the new needs of the future society for the teaching profession.
- Course Objective 5: Establish the life attitude and will quality of the combination of learning and thinking, the unity of knowledge and action, the courage to explore, the ability to solve problems, and the courage to explore and be creative in the 21st century.

4.1.2. Course Content

Based on the objectives of this course and the practical conditions of the maker space, four principles for content design have been established[53]. First, in terms of project design or technical skills, project content must present an appropriate level of difficulty and change. Students must complete project activities within the specified time frame by continuously thinking for themselves or actively seeking help, while applying their own knowledge and technical skills. Second, the six projects in the course are categorized into primary, intermediate, and advanced difficulty levels, reflecting a progressive relationship between technical skills and thinking from introductory projects to the final major project. Third, the course content is closely linked to students' current academic background and social life. Project content often originates from real-life contexts and can be applied back to our daily lives and work. Only by returning to real-life contexts can its value be realized[54]. Finally, after mastering the knowledge and techniques of making, students are guided toward developing a maker mindset during the creation process. Based on these four principles, this course has developed six projects, forming a comprehensive curriculum framework (see **Table 1**).

Table 1. Content of Maker Course.

Project Level	Project Theme	Skill Training	Maker Mindset	Key Thinking Points
Beginner: Regular Shapes	Name Tag	Rectangle, ellipse and text tools	Growth Mindset	Continuous iteration + pursuit of progress
Beginner: Semi-Regular Shapes	Creative Ruler	Rectangular array, breaking line segments	Innovative Mindset	Novelty & uniqueness + making connections
Intermediate: Irregular Shapes	Small Pendant	Outline tracing	Design Mindset	User-centric awareness + problem identification
Intermediate: Irregular Shapes	Chinese Zodiac Pendant	Hollow-out carving	Critical Mindset	Rational criteria + value evaluation
Advanced: 3D Structures	Civilization Slogan Sign	Mortise-and-tenon joint construction	Caring Mindset	Building relationships + empathetic design
Advanced: 3D Structures	Our City	Layered relief carving	Collaborative Mindset	Shared goals + teamwork coordination

4.1.3. Course Organization

Given that this maker education course is designed to foster "interest," facilitate "creation," and promote "self-actualization," its organizational structure incorporates the following eight elements: conceptual overview, scenario setting, task breakdown, project analysis, design and creation, instructional support, guided iteration, and reflection and discussion. See **Figure 2** for the specific course organization and learning model.

4.1.4. Course Evaluation

Evaluation is an activity in which an evaluator assesses an object; it is a process of making value judgments regarding the design and actual effectiveness of course activities through the collection and analysis of various information, data, and outcomes. In this course, the evaluators are the instructors and the learners. The objects of evaluation are the activity-based curriculum itself and the learners' academic performance. Specific evaluation details are provided in **Table 2**.

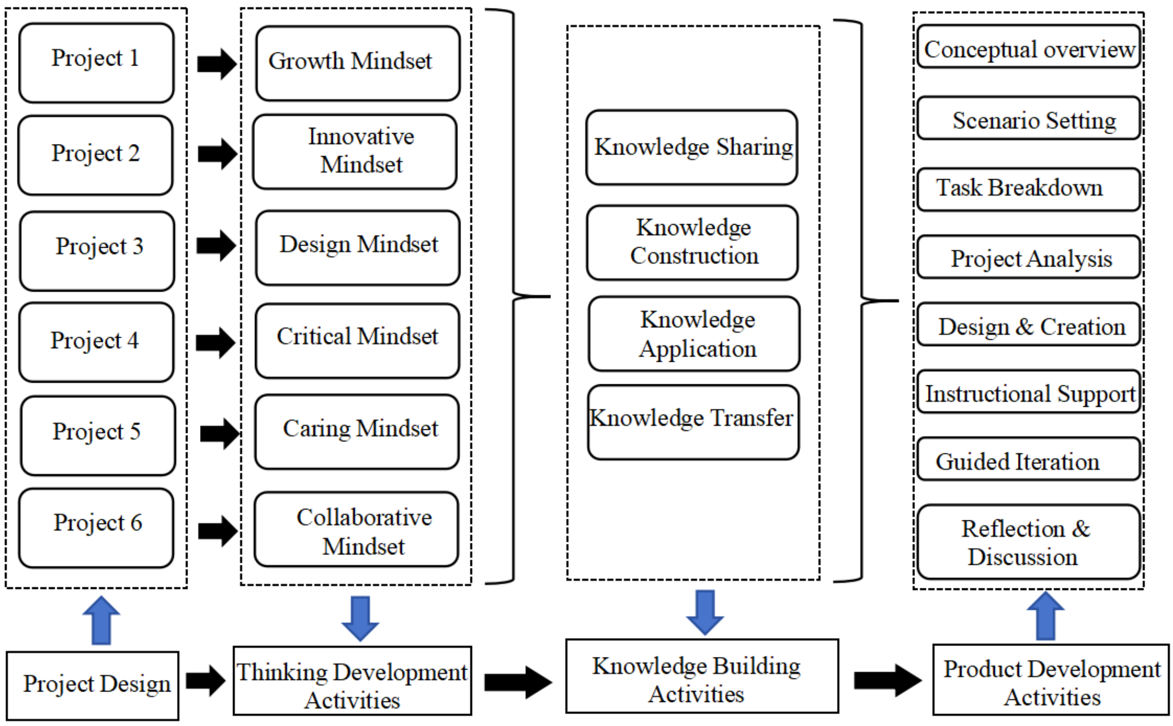

Figure 2. Maker Course Organization Structure.

Table 2. Teacher Evaluations of Maker Courses.

Overall Assessment		
Final Grade (50%)	Final Project (30%)	Integrate all maker creation skills learned to design and produce a work as required.
	Maker Practice Report (20%)	Present design ideas and process reflections in the form of a maker practice report.
Coursework Grade (50%)	Attendance (10%)	Full attendance is required. Students must submit a leave request in advance for special circumstances. Unexcused absences exceeding one quarter of total class hours will result in disqualification from the course.
	Class Participation (10%)	Group self-assessment and reflection. Peer review and whole-class discussion. Asking questions and seeking help.
	Project Practice (20%)	5 individual projects + 1 collaborative project.
	Thinking Training Form (10%)	Present design ideas and process reflections using the thinking training form as required.

4.2. Data Collection

This study adopts data triangulation to ensure empirical credibility. The research data cover three valid sources, including student learning portfolios, classroom video recordings, and representative student practical works (see **Table 3**). All data are authentic and directly generated from the actual curriculum implementation. Complete learning portfolios were collected from all participants throughout the nine-week course. These portfolios were developed under a unified instructional framework. They effectively record students' continuous learning trajectories and dynamic changes in maker mindset. Each student completed standardized weekly reflective journals. These written materials document real learning experiences, technical operation difficulties and progressive shifts in maker thinking during class practice.

Table 3. Students' Work Display.

Student Name	Major	Student Work	Student Name	Major	Student Work
YSS	Elementary Education (English)		JZH	Elementary Education (Science)	
CXY	Elementary Education (Chinese)		LXR	Elementary Education (Science)	
DZAW	Elementary Education (English)		LYR	Elementary Education (English)	
FJ	Elementary Education (Mathematics)		WHY	Elementary Education (Chinese)	
HJW	Elementary Education (Chinese)		ZSH	Elementary Education (Chinese)	

All participants submitted a comprehensive final innovation report at the end of the semester. The report summarizes their overall growth in interdisciplinary awareness and innovative problem-solving competence. Two core practical class sessions were fully recorded with the professional audio and video system provided by Ourdesk Technology (Tianjin) Co., Ltd. The high-definition and complete footage clearly captures students' in-class engagement, collaborative interaction and hands-on operational behaviors. Representative student maker works are also presented in the paper to intuitively reflect tangible curriculum learning outcomes. To guarantee data accuracy, one graduate student independently transcribed all recorded classroom data. The transcribed texts were peer-checked to eliminate errors and ensure full consistency with original classroom footage.

4.3. Data Analysis

This study applies systematic qualitative thematic analysis to process all empirical data, according to Creswell and Poth [55] and Saldaña [56], which includes data to codes, first cycle coding, and second cycle coding. Research data come from materials that include weekly reflective journals, final innovation reports and complete classroom video recordings. All raw data were carefully screened and sorted in the first step of data processing. Repetitive and irrelevant content was eliminated to ensure data validity. Only information related to student learning experience, practical difficulties, classroom performance and maker thinking development was retained.

The analysis followed standard qualitative coding procedures. Open coding was first used to extract initial concepts covering learning engagement, technical operation, practical innovation and mindset growth [57]. Axial coding further categorized these scattered codes into unified analytical dimensions [58]. The core categories include learning participation, practical competence, interdisciplinary integration and curriculum implementation limitations. Triangulation was adopted to enhance research rigor and credibility. Textual findings from long-term portfolio records were crosschecked with behavioral evidence from classroom videos. To further improve the objectivity of data analysis, a second graduate student independently conducted parallel thematic coding and analysis. The analytical results from two researchers were compared and cross-validated. Consistent conclusions were retained, and divergent items were discussed and unified. All research results are strictly based on empirical data.

5. Findings

Taking one particular class as an example, during the Practice of Maker and Intelligent Manufacturing Tools course held from October 23 to 30, 2025, in Room A202 of the local Innovation Building on campus, 10 elementary education students majoring in Elementary Science, Elementary Mathematics, Elementary Chinese, and Elementary English participated in the practice themed on "Civilization Slogan Signs and Caring Mindset", with the following instructional objectives: for knowledge objectives, students should be able to explain the meaning and characteristics of the caring mindset, describe the basic features of wooden mortise-and-tenon joints, and illustrate the scope of application for the Laser Maker "One-Click Creation" tool; for skill objectives, students should be able to proficiently use the Laser Maker "One-Click Creation" tool and complete the design and fabrication of a project featuring straight mortise-and-tenon joints through collaboration; for competency objectives, students should be able to consciously apply caring thinking during project practice, reflect on the relationships with themselves, others, natural objects, and man-made objects, and develop the mindset of caring for others. See **Appendix A** for specific course content and structure.

In terms of the knowledge evaluation, students can accurately interpret the connotation and essential characteristics of the caring mindset, and integrate empathetic design concepts into the creation of campus public signs. Meanwhile, students have grasped the structural principles and basic morphological features of wooden straight mortise-and-tenon joints, and applied such structural logic to the assembly and support design of physical works. In addition, students have a clear cognition of the functional attributes and application scope of the Laser Maker "One-Click Creation" tool, and can rationally utilize its engraving, cutting and structural modeling functions to complete the overall design and production of wooden works.

In the meantime, students have reached the expected standard in skill objectives cultivation. They are able to operate the Laser Maker "One-Click Creation" tool proficiently, with precise parameter setting, standard processing operation and neat finished effect in pattern carving and board cutting. In the practical project, students completed the whole process of scheme design, structural modeling, laser fabrication and physical assembly through effective team collaboration. They independently accomplished the customized production of works with straight mortise-and-tenon structures, showing solid hands-on making ability and collaborative practical competence.

Last but not least, students have realized the internalization and practical application of competency objectives in maker practice. They can consciously adopt caring mindset in project design and creation, fully consider the usage scenarios, audience perception and public aesthetic needs of the works, and embody humanistic care for individuals and campus public life. In the creation process, students have reflected on the interactive relationship between self, others, natural substances and artificial creations, established the awareness of respecting nature and optimizing public space environment, and gradually fostered the behavioral tendency and internal literacy of caring for others and serving the community with innovative design and maker practice.

This "Civilized Slogan Sign" creation activity was highly engaging, effectively stimulating students' enthusiasm and highlighting the characteristics of maker education. However, there were still some shortcomings. The following analysis of this classroom case will focus on both its strengths and weaknesses. First, this activity embodied the implementation phase of the maker learning model, progressing from guiding thinking and creating scenarios to breaking down project tasks, and then to teacher support, student design, and hands-on creation. Second, the activity focused on the understanding and practice of caring thinking, actively fostering new relationships guided by this philosophy and cultivating compassionate teachers who embody the principles of caring education. Third, the activity clearly demonstrated comprehensive and interdisciplinary attributes. During the design and creation process, students were guided by the objectives of problem-solving, completing projects, and fostering personal and professional growth, incorporating elements of engineering, artistic design, and mathematical computation.

However, although this activity process involves the use of computer Laser-Maker and laser cutting machine, there is no other place to reflect the advantages of information technology. The whole design process is relatively simple, lacking innovative meaning, and many students' works are similar. Furthermore, the connection between this activity and students' future academic subjects (elementary English, Chinese, and mathematics) was not particularly strong, as the projects were primarily creative works. For students, the educational value tied to academic disciplines requires further exploration.

6. Conclusions

Against the backdrop of ongoing basic education curriculum reform and the rapid advancement of educational modernization in China, this study focuses on the instructional activity design and practical implementation of pre-service teacher education courses tailored for prospective elementary school teachers within the framework of the maker learning model. It aims to break through the inherent limitations of traditional teacher-centered teaching modes, effectively respond to the realistic dilemmas and practical challenges in the systematic cultivation of maker-oriented teachers, and further support and facilitate the realization of the national strategic goal of fostering high-quality, professional, innovative and outstanding teachers by 2035 in China [59]. As Li Biwu pointed out, the widespread promotion and implementation of maker education at the primary and secondary education levels currently faces a prominent bottleneck of the severe shortage of qualified maker teachers with professional literacy and practical innovation abilities [30]. In response to this pressing demand, this study takes the professional elective course Practice of Maker and Intelligent Manufacturing Tools offered at teacher-training universities as the research carrier. Through deliberate curriculum planning, systematic classroom activity design and in-depth teaching implementation, the paper explores feasible training paths, and provides new insights into the practical operational methods for the standardized cultivation and professional development of maker-oriented pre-service teachers.

One of the core research issues addressed in this study is the exploration of what essential professional qualities and core literacy a competent maker-oriented teacher should possess. This study proposes that qualified maker-oriented teachers must embody six key maker mindsets, including growth mindset, design mindset, innovative mindset, critical mindset, collaborative mindset, and humane care mindset. Beyond these fundamental mindsets, maker-oriented teachers should also develop comprehensive competencies such as interdisciplinary knowledge integration, practical problem-solving abilities in real educational contexts, effective teamwork skills and independent innovative practice capabilities, so as to fully adapt to and satisfy the diverse and personalized educational demands of modern elementary education.

This lesson study investigates the practical effects and existing limitations of an interdisciplinary maker education curriculum. The research is situated in the localized context of pre-service primary teacher education. The curriculum design effectively enhances pre-service teachers' learning initiative and practical participation in classroom activities. It realizes the core practical value of maker-oriented teaching in normal university education. However, all findings are context-specific and derived from this single nine-week curriculum intervention. The results can only provide targeted references for the optimization of similar maker education practices, without universal applicability to broader teacher education scenarios.

Although this study has achieved positive practical outcomes in curriculum practice and teacher training exploration, the overall implementation process has also exposed several noticeable shortcomings. These include insufficient in-depth application of information technology means in classroom teaching, a relative lack of breakthrough innovation in teaching design, and weak internal connection between maker practice activities and students' subject-specific professional education. In future research and teaching practice, it will be necessary to further optimize the overall curriculum framework and activity arrangement, strengthen the deep integration of information technology and maker teaching, continuously enhance the innovative value and practical applicability of the curriculum, reinforce links between maker education and subject training, and gradually refine and improve the whole training system for maker-oriented teachers. In doing so, it can provide solid support for the long-term cultivation of outstanding elementary school teachers who can well adapt to the developmental demands of the new era.

Author Contributions

Conceptualization, D.Y.; methodology, D.Y.; software, D.Y.; validation, D.Y. and X.Z.; formal analysis, D.Y.; investigation, D.Y.; resources, D.Y.; data curation, D.Y.; writing—original draft preparation, D.Y.; writing—review and editing, X.Z.; visualization, X.Z.; supervision, X.Z.; project administration, D.Y.; funding acquisition, D.Y. Both authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement

This lesson study collects data from mandatory university course archiving materials, including classroom recordings, pre-service teachers' reflective reports and maker practice works. These documents are standard coursework submissions without sensitive private information. All identifiable personal information in recordings and texts has been anonymized. The University only sets up internal ethical review procedures for biomedical, psychological and brain imaging experiments involving physiological data collection. For low-risk educational lesson studies based on routine classroom teaching and course archive materials, there is no formal Institutional Review Board (IRB) submission channel, and no dedicated ethical protocol code will be issued by the university.

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study. All participants were fully informed that their course materials would be used for teaching research and provided voluntary consent.

Data Availability Statement

The data used in this study are available at the following links: student learning portfolios: https://pan.baidu.com/s/1cCd9u1WO2SOy9Oo9UCFWKA?pwd=sjip, access code: sjip; classroom video recordings: https://pan.baidu.com/s/1J7MzpvLZV5iTt57rAgQOlg?pwd=3hkr, access code: 3hkr; knowledge evaluation: https://pan.baidu.com/s/1UvN96tocG4thhjfHsRi94w?pwd=sae4, access code: sae4.

Conflicts of Interest

The authors declare no conflict of interest.

AI Use Statement

During the preparation of this manuscript, the authors used Doubao solely for language refinement. No AI tools were used for introduction, literature review, data collection/analysis, or generation of any scientific data. All outputs were critically reviewed and edited by the authors. The authors take full responsibility for the integrity and accuracy of the work.

Appendix A

Table A1. Course Content and Structure.

Phase	Teacher Actions	Student Actions
Conceptual Overview	The teacher introduces the course theme of civilized signboards and caring thinking. The teacher invites students to complete a self-assessment of caring thinking. The teacher explains the definitions of care and caring thinking.	Students get fully prepared for the lesson. They understand the perspectives to interpret concepts including care and caring thinking. They conduct continuous reflection on the relationships they have built with others and the external world in their past studies and daily life. They finish the corresponding self-assessment.

Table A1. *Cont.*

Phase	Teacher Actions	Student Actions
Scenario Setting	The teacher assigns and describes the learning task. The teacher asks students to depict an uncivilized phenomenon on the university campus. Then the teacher asks students to design and produce a civilized signboard based on the phenomenon. The signboard is expected to deliver a warm reminder to all viewers. The specific requirement for the task is to reflect caring thinking and the target of care.	Students clarify the requirements of the assigned task. They break down the task based on their initial personal understanding. They form expectations for the completion of Creation Version 1.0.
Task Breakdown	The teacher offers prompts for the definition of civilized slogans. The teacher guides students to reflect on the relationship between themselves and the university. The teacher leads students to list the problems found around them. The teacher encourages students to reflect on appropriate ways to put forward warm reminders.	Students integrate caring thinking into their learning process. They gain a deeper understanding of the task scenario. They clarify the thinking perspectives for the task. They answer the guiding questions from the teacher. They express their preliminary expectations for the final work.
Project Analysis	The teacher clarifies the specific requirements for the project. The teacher asks students to explore how to demonstrate their spatial imagination and assembly practice of mortise and tenon structure components under the creation requirements of civilized signboards. Then the teacher invites students to explain their thinking and creation process orally through self-assessment and peer assessment.	Students learn the core concepts and design process of mortise and tenon structures. They master relevant techniques through completing the straight tenon structure of the "Flying Dove" model. Students draft the design drawings of their creation. They complete the creation practice with a laser cutting machine. They fill in the thinking training form after the practice. They present their finished works to the whole class.
Design and Creation	The teacher allocates around 45 min for students to complete the design drawings as well as the cutting and assembly of Version 1.0 of the work.	Students follow the teacher's requirements. They integrate the knowledge they have learned. They complete the corresponding creation practice.
Guided Iteration	The teacher conducts roving guidance among students. The teacher gives comments on the completed Version 1.0 works. The teacher guides students to make improvements. The teacher invites students to complete the cutting and production of Version 2.0 after revision.	Students listen to the reasonable suggestions from the teacher and their peers. They make active revisions accordingly. They complete the production of Version 2.0 of the work.
Reflection and Discussion	The teacher organizes students to introduce their works within groups. The teacher arranges for students to share their experience of design and creation with the whole class. The teacher facilitates peer assessment and reflective communication activities.	Students introduce the design concept of their works both in groups and to the whole class. They share their learning insights on caring thinking. They also share their creation experience of making the civilized signboards.

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