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Research on the Application of STEAM-X Teaching Mode in Secondary Vocational Education: A Case Study of "Python Programming" Course

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Abstract

With the development of vocational education and industrial upgrading, secondary vocational schools, as the bases for cultivating technical and skilled talents, are in urgent need of teaching model reform. The STEAM-X teaching model incorporates the extended element X on the basis of interdisciplinary integration of STEAM. It delivers holistic education centering on real-world problems, breaks disciplinary boundaries, and focuses on fostering students' innovative and practical capabilities. At present, its application in domestic vocational education is still in the exploratory stage. This paper explores the application and effects of this model in the secondary vocational course Python Programming, so as to provide references for curriculum reform in secondary vocational education. The paper sorts out the theoretical foundation, concepts and advantages of STEAM-X in vocational education. Different from the traditional teaching that focuses merely on grammar learning, this model integrates project design and logical training. It matches the characteristics of secondary vocational students, helps stimulate their learning interest and develop their abilities of independent inquiry, collaboration and innovation. Taking the chapter "Integration of Python and Artificial Intelligence" from the textbook as a case, teaching design and practice are carried out. This chapter involves abstract concepts and requires strong practical skills. Practical results show that the STEAM-X model improves students' classroom engagement and deepens their understanding of artificial intelligence and programming technology. The study summarizes practical experience and puts forward optimization strategies, including adjusting teaching design to adapt to students' cognition, improving the assessment of learning processes, and strengthening teachers' teaching competence. In conclusion, the STEAM-X model achieves favorable outcomes when applied to the secondary vocational Python course and offers new ideas for the teaching reform of secondary vocational education and similar courses.

Keywords

STEAM-X Teaching Model; Secondary Vocational Curriculum; Python Programming; Artificial Intelligence; Vocational Education

1. Background and Significance of the Study

China's vocational education has entered a high-quality development stage focused on quality improvement and excellence cultivation. The digital transformation of industries has changed enterprises' requirements for secondary vocational talents: expectations have shifted from simple operational skills to comprehensive professional competencies such as interdisciplinary application, innovative practice and so on. Traditional teaching modes featuring subject-based lectures and imitative practice have drawbacks including disconnection between curriculum content and job requirements, and insufficient innovative and practical abilities among students. Hence, a new integrated teaching mode is urgently needed. STEAM education advocates interdisciplinary, project-based learning by doing, which aligns with the practice-oriented philosophy of vocational education. Built on the STEAM framework, the STEAM-X model introduces the extended element X. It can integrate localized content such as job demands, moral education, innovation and entrepreneurship, overcoming the limitation that conventional STEAM is overly general. This makes it suitable for the job-curriculum alignment teaching in secondary vocational education. At present, STEAM-X is mostly applied in basic education, while its applications in information technology courses of secondary vocational schools remain limited. Conducting research on STEAM-X teaching for *Python Programming* meets the practical demands of secondary vocational curriculum reform and the integration of posts, courses, competitions and certificates, and can also enrich the teaching theories of vocational education.

The advancement of artificial intelligence technology raises higher standards for cultivating computational thinking and engineering practice ability in secondary vocational information courses. Existing courses suffer from abstract theories, inadequate practical sessions and fragmented disciplines, making it difficult to realize the integration of theoretical knowledge and practical training across disciplinary boundaries. Relying on multidisciplinary integration, the STEAM-X model builds scenario-based teaching with the support of the X element. It matches the features of artificial intelligence courses that emphasize application and innovation. Nevertheless, mature implementation pathways of this model are still lacking for secondary vocational artificial intelligence courses. Relevant research helps improve teaching effectiveness and foster digitally-skilled technical talents.

Secondary vocational students are strong in visual thinking and hands-on operation, yet they show low motivation for theoretical study and hope to gain a sense of achievement through practice. Traditional teaching methods that prioritize theoretical memorization tend to dampen students' enthusiasm for learning. Centered on project inquiry and interdisciplinary practice, STEAM-X improves learning experience through visual learning outcomes and fits the cognitive characteristics of secondary vocational students. However, this model has not been widely implemented in secondary vocational classrooms. Related research can

effectively stimulate students' learning motivation and promote their all-round development.

This study conducts an in-depth analysis and summary of the specific implementation process and effects of the STEAM-X model in classroom teaching for the chapter "Integration of Python and Artificial Intelligence" in the textbook *Python Programming*. It extracts teaching patterns and experience suitable for the characteristics of secondary vocational education. Such experience and models can provide references for other secondary vocational schools and teachers in teaching reform, and promote the innovation and development of teaching modes in secondary vocational education.

The STEAM-X teaching model can not only overcome the limitations of traditional teaching approaches, but also cultivate students' multi-faceted abilities, improve teaching effectiveness and quality, and advance the integration of vocational education and industry. Therefore, the STEAM-X model should be actively promoted and applied in vocational education and curriculum instruction.

2. Research Status at Home and Abroad

2.1. Foreign Research Status

STEAM education evolved from STEM education. STEM collectively refers to the education of four disciplines: Science, Technology, Engineering and Mathematics. The number of graduates obtaining STEM degrees was once regarded as an important indicator for measuring national competitiveness. Later, the United States government incorporated Arts into the STEM framework [1] to promote the integration of technological and engineering education with arts and humanities education, and thus STEAM education came into being. Rather than a simple accumulation of multidisciplinary knowledge, STEAM education integrates various disciplines into a unified teaching paradigm, assembling fragmented knowledge into an interconnected whole. It advocates problem-oriented interdisciplinary teaching and represents a multidisciplinary integrated education model that focuses on comprehensive competence and thinking development. As an innovative education system, the effective implementation of STEAM education can cultivate learners' problem-solving skills, creativity and critical thinking, so as to enhance national comprehensive competitiveness [2].

Foreign research on artificial intelligence teaching based on the STEAM philosophy has achieved certain results. A typical example is Scratch, a graphical programming software developed in the United States. Compatible with multiple operating systems and translated into more than 60 languages, it is widely adopted in information technology classrooms across many countries. Chinese scholars have also begun to pay attention to information technology teaching under the STEAM concept. A retrieval on CNKI with the topic "STEAM education" and "secondary vocational education" yields 93 relevant documents. Artificial intelligence courses

serve as a comprehensive upgrade of disciplinary content in secondary vocational education and occupy a prominent position within its teaching system. Having received prior learning, secondary vocational students have mastered basic knowledge related to artificial intelligence. Information technology teaching carried out under the STEAM philosophy can consolidate students' information technology knowledge and improve their practical skills. Meanwhile, it can expand the boundaries of learning with digital technology and foster innovative thinking and awareness.

Overall, domestic research applying STEAM education to secondary vocational teaching is still relatively inadequate and remains immature. Relevant theoretical and practical achievements need to be enriched. More scholars are required to conduct in-depth research to improve the teaching theories and practical schemes of STEAM applied in secondary vocational classrooms.

2.2. Domestic Research Status

Domestic research on the STEAM-X teaching model started later than that abroad. Although integrated practical activity courses, labor technology courses have been offered, science and technology clubs established and innovative education carried out in China for a long time, these efforts are not equivalent to research on STEAM education. The theory of STEAM education originated in the United States. China introduced this concept and then carried out localized practice and theoretical exploration. A search on CNKI using the keyword "STEAM teaching concept" retrieved 1628 Chinese documents. Annual statistics of the literature show that the number of relevant papers has kept increasing since 2018, indicating growing attention to research on the STEAM teaching concept in China.

In terms of theoretical research on the STEAM-X teaching model, Peng Min and Guo Mengjiao et al. (2018) sorted out the background of the evolution from STEM to STEAM, distinguished divergences in academic viewpoints, defined three core connotations of STEAM, and put forward three localized implementation paths covering curriculum resources, teaching methods and teacher training, so as to improve the theoretical framework of STEAM education [3]. Liu Zhongwen and Liu Haibin et al. (2021) addressed practical difficulties in domestic STEAM teaching such as disciplinary fragmentation and insufficient resources. They clarified the conceptual boundaries among STEAM, maker education and PBL, integrated the localized education philosophy of cultivating people, constructed an integrated practical model, and explored localized STEAM implementation approaches suitable for large-class teaching [4]. Xiao Qingxia et al. (2024) summarized the interdisciplinary, contextualized and project-driven features of STEAM, built a four-layer cyclic PBL teaching model for the environmental design major, and formed a referable teaching paradigm for university design majors combined with landscape design cases [5]. Zhou Yage et al. (2025) established a three-layer

interdisciplinary curriculum system according to the characteristics of the intelligent logistics major and designed diversified teaching and evaluation modes, providing references for the teaching reform of interdisciplinary majors combining engineering and business [6]. Ye Jinghong et al. (2026) focused on the five-year higher vocational electromechanical major, constructed a digital and intelligent training framework of "one core, two wings and three integrations", and improved the system of practical training, teaching, evaluation and support, filling the gap in research on the systematic implementation of STEAM in vocational education [7].

With regard to applied research on the STEAM-X teaching model, primary and secondary schools in China have offered integrated practical courses, science courses and others under the STEAM concept with relevant policy support, and many scholars have devoted themselves to exploring teaching practices. Zhou Dongdai reconstructed the primary school curriculum system; Hou Ye and Liu Fengjuan applied the STEAM concept to information technology classes in primary and secondary schools; Zheng Xian designed and implemented 3D printing courses. STEAM-related courses are widely available in primary and secondary schools, and explorations have also been made in higher education to foster students' innovative and practical abilities. It is essential to introduce STEAM education into secondary vocational education. As an extended model of STEAM education, STEAM-X features greater flexibility and comprehensiveness. It matches the training objectives of skilled talents in secondary vocational education, helps improve students' overall literacy, meet industrial post requirements and optimize classroom teaching in secondary vocational schools.

3. Research Content and Methods

This study carries out teaching practice in traditional secondary vocational classrooms by adopting the STEAM-X teaching model to explore its applicability and feasibility in the secondary vocational course *Python Programming*. The specific research content is divided into several stages: research preparation, preliminary research, research implementation, and research summary.

This paper explores in depth the specific application of the STEAM-X teaching model in secondary vocational education, particularly its practical effects on the key teaching unit "Integration of Python and Artificial Intelligence" in the textbook *Python Programming*. This research adopts the practice verification method in authentic teaching contexts and conducts practical exploration in artificial intelligence teaching at secondary vocational schools. It comprehensively uses educational research methods including research synthesis, action research and questionnaire survey to investigate the application of the STEAM-X teaching model in artificial intelligence courses at secondary vocational schools.

4. Core Concepts and Theoretical Basis

4.1. Definition of Relevant Concepts

The STEAM-X teaching model is an innovative teaching paradigm that adds a variable "X" dimension to conventional STEAM (Science, Technology, Engineering, Arts and Mathematics) education to achieve in-depth expansion and cross-border integration. Breaking the barriers among the original five disciplines, this model can incorporate more fields, competencies and themes to build an interdisciplinary education system adapted to the development of the times. STEAM serves as the basic framework, focusing on the integration of knowledge from the five disciplines and learning by doing. As a dynamic variable, X stands for flexibly expandable disciplines, competencies or themes. It is the core of STEAM-X and endows the model with strong adaptability and expansibility. Traditional STEAM features a fixed disciplinary combination and a relatively closed system. By contrast, STEAM-X can be regarded as the upgraded version 2.0 of STEAM education. The dynamic variable X broadens the breadth and depth of teaching, aiming to cultivate interdisciplinary innovative talents capable of coping with complex future challenges.

Rather than a simple superposition of multidisciplinary knowledge, STEAM-X is driven by real-world problems or projects. It promotes deep integration between STEAM and X to realize knowledge penetration and develop students' comprehensive ability to solve complex problems. Student-centered teaching is adopted, with inquiry-based and project-based learning (PBL). Students construct knowledge independently by following the procedure of "theme inquiry -prototype design-iterative optimization", while teachers shift from knowledge lecturers to guides and collaborators.

Teaching content is rooted in real life and social contexts. Great importance is attached to hands-on practice, tool application and output of works so as to integrate knowledge with practice. The variability of the X dimension enables courses to dynamically adjust teaching content in response to advances in technology and society, and effectively fosters students' future-oriented core competencies.

4.2. Relevant Theoretical Basis

Constructivism is an important theory in modern educational psychology. It refutes the behaviorist view of passive learning and holds that knowledge is not transmitted unilaterally by teachers. Instead, learners actively construct meaning in specific contexts with the help of others on the basis of their prior experience. Learning has four major characteristics: situatedness, initiative, sociality and constructiveness. It advocates that teachers transform from knowledge transmitters to learning facilitators and adopt project-driven teaching, collaborative inquiry and other teaching methods. Constructivism provides theoretical support for the STEAM-X model. By creating complex learning contexts based on real projects, STEAM-X prevents knowledge from being abstract and fragmented. Students engage in

independent design and hands-on practice to actively complete cognitive construction, deepen understanding through group cooperation, while teachers only offer support rather than directly providing answers [8]. As a practice of constructivism in innovative education, STEAM-X facilitates students' deep learning and improves their innovative and comprehensive abilities.

The Theory of Multiple Intelligences was proposed by Gardner. It breaks the traditional view that intelligence is measured merely by linguistic and logical-mathematical abilities. The theory states that human beings possess multiple relatively independent intelligences including linguistic, spatial, bodily-kinesthetic and interpersonal intelligences, and each individual has a unique combination of intelligence strengths. Education should respect individual differences, develop students' dominant intelligences and advocate diversified evaluation. This theory provides value foundations for STEAM-X. The STEAM disciplines correspond to logical, spatial and aesthetic intelligences, while the dynamic X dimension further expands the cultivation of intelligences such as interpersonal, intrapersonal and naturalist intelligence. Through diversified activities including project creation and achievement demonstrations, STEAM-X offers opportunities for students with different characteristics to display their strengths. It adopts comprehensive process evaluation instead of score-only assessment. STEAM-X realizes personalized education and promotes the coordinated development of students' multiple potentials.

Situated Cognition Theory emerged in the 1980s. It argues that cognition is rooted in real contexts and knowledge is generated through interaction in social practice. Learning refers to a process in which learners gradually participate and internalize abilities within communities of practice. It attaches great importance to authentic contexts, social interaction and practical experience. This theory is highly consistent with STEAM-X. Authentic contexts serve as the carrier for interdisciplinary integration in STEAM-X; multidisciplinary knowledge can be flexibly applied in scenarios such as engineering design and creative production. STEAM-X builds authentic inquiry scenarios through project-based learning and guides students to construct knowledge collaboratively. Both reject rote memorization and focus on cultivating problem-solving skills and innovative literacy. Situated cognition guides the design of teaching scenarios for STEAM-X, while STEAM-X puts the idea of situated cognition into practice. Together, they foster students' practical capabilities and deep learning [9].

5. Feasibility Analysis of the STEAM-X Teaching Model in the Python Programming Course

1. High Compatibility at the Theoretical Level, Consistent with the Interdisciplinary Educational Logic of the Course

According to the core connotations of STEAM (interdisciplinarity, project-based

learning and situated inquiry) proposed by Fan Wenxiang and Zhang Yichun (2018), the Python course inherently integrates multidisciplinary elements: mathematics for data calculation and logical modeling, technology for function realization via programming tools, engineering for modular program development, arts for beautifying visual interfaces, and science for exploring rules through data analysis. Based on the five disciplines, STEAM-X adopts the variable X dimension to align with the teaching objectives of programming courses. The two share a matched theoretical system and possess a foundation for implementation [10].

2. The Expanded X Dimension Precisely Addresses Existing Pain Points in Secondary Vocational Python Classrooms

Secondary vocational Python teaching is confronted with obvious student differentiation, disconnection between industry and education, and separation among posts, courses, competitions and certificates. The extended variable X in STEAM-X can be flexibly set as professional post cases, 1+X digital skill certificates, programming contests and corporate automation projects. Basic STEAM tasks ensure underachieving students master fundamental grammar, while X extended tasks enable advanced students to pursue further improvement. Such differentiated design effectively eases student polarization and remedies the drawback that traditional teaching content is divorced from vocational scenarios.

3. Unified Practical Project Carriers Matching the "Learning by Doing" Attribute of Python

STEAM-X centers on authentic differentiated projects as core teaching carriers, which perfectly fit the characteristics of the Python Programming course that emphasizes practice, debugging and output of deliverables. Laddered programming projects can be designed for the course. At the basic level, students complete comprehensive STEAM tasks such as drawing and simple data processing. At the X extension level, they develop professional automation scripts for finance, e-commerce, electromechanics and other majors. Teaching proceeds throughout via hands-on coding and repeated trial-and-error iteration, meeting the STEAM education requirements of "inquiry in authentic contexts and making through practice".

4. Diversified Evaluation System Meeting the Assessment Reform Needs of Programming Courses

Traditional evaluation for Python courses relies on written examinations and single programming assignments, which fail to assess logical thinking, debugging competence and professional norms. STEAM-X establishes a dual evaluation system of "basic literacy + X extended competencies". It assesses fundamental STEAM abilities including coding and project workflows, and incorporates contest criteria, enterprise development specifications and practical requirements of certificates through the X dimension. It realizes process-oriented and comprehensive evaluation, optimizes the current course assessment framework, and implements evaluation

standards for digitally skilled talents in secondary vocational education.

6. Teaching Implementation and Result Analysis

This study carried out comparative teaching practice in two classes of the Big Data Technology and Application major, Grade 2028 at Chongqing Hailian Vocational and Technical College. Each class consisted of 40 students with a relatively balanced gender ratio. Class Big Data 2801 was set as the experimental class and taught artificial intelligence courses with the STEAM-X teaching model. Theoretical and practical lessons were closely integrated to realize integrated teaching, in which the explanation of theoretical knowledge was embedded in practical activities. Class Electronics 2802 served as the control class and received artificial intelligence instruction via the traditional lecture-based method: theoretical knowledge was delivered first, followed by practical laboratory sessions. The same textbook was adopted for artificial intelligence teaching in both classes, and careful planning guaranteed consistency in key factors such as the teaching environment and teaching schedule. These measures aimed to control potential confounding variables to the greatest extent and ensure the accuracy and reliability of experimental results.

Courses for the control class were divided into new-lesson lectures and laboratory sessions. New-lesson procedures included pre-class preparation, lesson introduction, knowledge lecturing, in-class exercises, and summary and evaluation. Teachers demonstrated, elaborated on and analyzed learning content mainly through lectures and presentations. Laboratory sessions were arranged after theoretical lectures to examine students' ability to apply learned theories in practical operations.

The teaching design for the experimental class was developed according to the features of the STEAM-X teaching model. Instruction was implemented following the stages of "scenario introduction-problem decomposition-collaborative inquiry -testing and iteration-achievement presentation-review and reflection". Scenario introduction usually adopted operable events related to the learning content to construct authentic vocational scenarios, clarify project tasks and incorporate X extended elements. For instruction in the experimental class, first of all, the teacher helped students form groups following the principle of heterogeneous grouping within groups and homogeneous grouping between groups, with roughly 3 to 4 students per group. Cooperative group learning functioned as an auxiliary component in the STEAM-X model. In the actual teaching process, teachers actively built an atmosphere for autonomous learning, granted students sufficient room for exploration and encouraged them to discover learning resources independently. Students communicated and discussed actively within groups and conducted in-depth learning around carefully designed scenarios. Teachers offered timely guidance and prompts to stimulate students' initiative and consolidate their

dominant position in learning.

In terms of assessment, the control class adopted a comprehensive evaluation combining class attendance, usual performance and final examination. The experimental class adopted comprehensive evaluation through student self-assessment, peer assessment within groups, teacher assessment, observation of problem-solving performance, and tests.

After one semester of experimental teaching, significant differences were observed between the experimental class and the control class in learning outcomes of artificial intelligence knowledge, learning interest and attitudes, learning methods and habits, as well as comprehensive literacy. Guided by authentic scenarios, students in the experimental class achieved remarkable improvements in hands-on practice and problem-solving abilities, accompanied by better academic performance. More importantly, some students gained a sense of achievement and self-identity during task completion. Such positive feedback further aroused their interest in artificial intelligence learning and formed a virtuous cycle of learning and progress. This study strongly proves that the STEAM-X teaching model matches the learning characteristics of secondary vocational students and satisfies the teaching objectives and demands of secondary vocational education. Appropriately designed scenario-based problem decomposition can effectively promote students' all-round development, strengthen their intrinsic learning motivation, improve their multiple competencies, and better meet social demands for secondary vocational talents.

The final evaluation of teaching effects indicates that the application of the STEAM-X teaching model not only greatly enhances secondary vocational students' learning confidence and interest in the Python Programmingcourse, but also exerts positive effects on the improvement of their comprehensive abilities. It provides solid practical support for curriculum reform and teaching quality improvement in secondary vocational education.

7. Future Prospects

Teaching research is a long-term process, and there remain many issues worthy of further exploration regarding the application of the STEAM-X teaching model in secondary vocational curriculum instruction. First, restricted by objective conditions, this research has a relatively short research cycle, narrow experimental scope and small sample size. Further analysis and discussion are required to verify whether this teaching model is applicable to students from other schools or the teaching of other disciplines. Second, some teaching activities under the STEAM-X model are carried out in the form of group cooperation. How to realize reasonable task allocation within groups so that every student can develop and give full play to their strengths remains to be explored through further practice.

This study is only a preliminary exploration of applying the STEAM-X teaching model to secondary vocational courses. Future research should expand the

experimental scope and sample size as much as possible, implement teaching practice of the STEAM-X model in other secondary vocational courses, remedy the deficiencies of this study, and optimize its application framework in secondary vocational education. These efforts will make the research findings more convincing and reasonable, facilitate deeper integration between the STEAM-X teaching model and secondary vocational teaching, improve the learning performance of secondary vocational students, and promote the sustainable development of secondary vocational education.

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