AI-Assisted Shadow Learning Oriented to Cultivation of Interdisciplinary Innovation Ability of College Students

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Abstract. From the perspective of the interdisciplinary innovation ability cultivation of college students, this paper discusses the shadow learning paradigm, analyzes six problems that may exist in the implementation process, and proposes feasible AI-assisted solutions based on ChatGPT and generative artificial intelligence. The six issues in the shadow learning paradigm include the limitation of knowledge boundaries, personalized learning objectives and plans, customized assessment, novel study methods, additional learning support, and effective communication. The corresponding solutions include personalized knowledge graphs, plan automatic generation, test automatic generation, virtual reality and multimodal resources, virtual community and ChatGPT, and intelligent virtual workspace.

Keywords: Shadow Learning; Interdisciplinary Innovation; Cultivation of Innovation Ability, ChatGPT, Generative AI.

1 Introduction

The cultivation of innovation ability is one of the core contents of quality education and an essential part of college students' education system. Innovation ability has been described and defined by relevant institutions and many scholars. China's Core Competence Assessment Outline - Innovation Capability (Trial), published in 2002, defines innovation capability as "the ability to creatively propose discoveries, inventions, and new improvement and innovation schemes based on previous discoveries or inventions through own efforts." Its main characteristics are acuity, criticality, pioneering, novelty, and originality " [1]. Chu believes that innovation ability is the advanced expression of human psychological function. It has four dimensions: innovative thinking process, creative achievements, innovative personality characteristics, and innovative environment [2]. Zhong also mentioned that "according to a certain purpose, the so-called innovation ability is the advanced expression of human psychological function, that is the intellectual quality or ability of an individual to use all known information to create some novel, unique and socially or personally valuable products in the process of learning scientific knowledge, solving scientific problems and scientific creation activities" [3].

In recent years, due to many new scientific discoveries or significant technological innovations in interdisciplinary fields, complex problems that are difficult to solve by single-field expertise

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effectively have been solved [4]. Therefore, multidisciplinary innovation has become an important research direction, and interdisciplinary education has also become essential for training innovative talents [5]. Zhan figured out that "the so-called interdisciplinary innovation ability refers to the ability to solve problems in a novel and unique way and produce valuable new ideas, new methods, and new results in some creative activities under one's personality quality and the use of existing interdisciplinary and cross-field knowledge and experience" [6]. Bao introduced that since the implementation of the Excellence Program in Germany in 2005, "Excellence clusters" have been set up expressly to support the development of interdisciplinary research [7]. College students' interdisciplinary innovation ability can often be reflected by innovative project development involving students from different disciplines in the competition and scientific research teams. Bi mentioned, "Collaborative innovation of university interdisciplinary research organizations refers to an organizational management innovation in which university interdisciplinary research organizations collaborate with enterprises and other participants to jointly produce, disseminate and transfer knowledge around the significant needs of science and technology, economy and social development. The core of this innovation depends on effective collaboration" [8]. Chen comprehensively evaluated the influence and change of AI on modern teaching mode in an all-round way [9].

In the collaborative innovation process of college student competition teams or scientific research teams, each participant needs to understand the task's requirements and can communicate with each other effectively to jointly analyze and solve complex interdisciplinary problems with others. However, in practical activities, students are often confronted with issues, including a lack of specific knowledge, lack of expertise in other cooperative disciplines, and lack of effective communication methods across disciplines. In the actual research or R&D projects, the knowledge required consistently exceeds the scope in the syllabus of the student's major. Thus, students have to extend their knowledge domain through shadow learning methods. From the perspective of cultivating the interdisciplinary innovation ability of college students, this paper explores the "Shadow Learning" paradigm, clarifies the goal of shadow learning, and promotes interdisciplinary communication and knowledge transfer via state-of-the-art AI technology. Since shadow learning combines knowledge storage and knowledge transfer in digital knowledge management [10], state-of-the-art AI techniques are utilized to resolve the general problems of shadow learning.

2 Shadow Learning

Due to the team's cooperation, the "shadow learning" mode is often adopted to expand the knowledge boundary of the traditional syllabus and promote the knowledge acquisition and creation of new group members. In the robotic surgery skills training process, Beane figures out that the residents with excellent evaluation like to use shadow learning mode to improve their skills when they cannot effectively master skills in the standardized training process. These doctors can master relevant robotic surgery skills in a non-standardized way under limited supervision. This learning mode differs from the standardized training process: premature specialization, abstract rehearsals, and under-supervised struggle [10-11]. Regarding teacher training in primary and secondary school, Wang proposes the "shadow learning" mechanism, which constructs, generates, and integrates empirical knowledge from real situations and relies on the multi-subject learning community to carry out interactive, participatory, reflective, and long-term unsupervised learning. In this "shadow learning" process, primary and secondary school teachers play the role of "shadow," imitate and follow up with the "tutor," experience, think, and learn the tutor's behavior, philosophy, and thinking mode. This "shadow learning" mechanism differs from traditional teacher training in that it emphasizes autonomy, experience, and continuity and co-constructs knowledge with colleagues and experts for specific issues in their work. It includes not only formal teacher training but also informal learning activities in the workplace and life situations in addition to formal learning [12].

It differs from the shadow learning mechanism of primary and secondary school teacher's training, which emphasizes following the footsteps of tutors to complete projects. It also differs from the shadow learning strategy of robot surgery skills training to master professional operating skills through unconventional practice methods. Its goal is to gain collaboration skills, creative thinking, and knowledge innovation through the learning and integration of interdisciplinary knowledge during the project development.

However, as with other shadow learning scenarios, the following are co-existence, including:

1. Blurry learning objectives. Due to the lack of relevant interdisciplinary knowledge, students cannot fully understand the scope and objectives of the project, which include the parts beyond the knowledge domain of students. Thus, they are blurry about the learning objectives of unknown knowledge.

2. Inappropriate learning plan. Due to noticeable individual differences, each student should have a learning plan suitable for their development. They must complete specific learning tasks and assessments in stages according to their task assignment. However, students generally cannot customize effective learning plans in light of the whole knowledge system understanding limitation.

3. Undersupervised struggle. In the research and development process, students need to solve complex problems and fulfill tasks through their efforts under the limited guidance of supervisors, which is crucial for improving practical ability and innovation ability. Getting additional support is the key to the success of the shadow learning strategy.

4. Premature specialization. For junior college students, early interdisciplinary knowledge learning will occupy their time to learn the fundamental knowledge of their major. Reasonable limitations of the multidisciplinary knowledge boundary, which involves project-related understanding, are the balance and trade-off that must be carried out in shadow learning to ensure efficiency.

5. Abstract rehearsals. In shadow learning, interdisciplinary knowledge learning is not carried out like regular courses, and the students are prone to the problems of knowledge fragmentation and one-sided understanding. Therefore, shadow learning often requires learning methods beyond the conventional teaching process through multimodal or simulation to strengthen the learning effect.

3 Paradigm of AI-assisted Shadow Learning

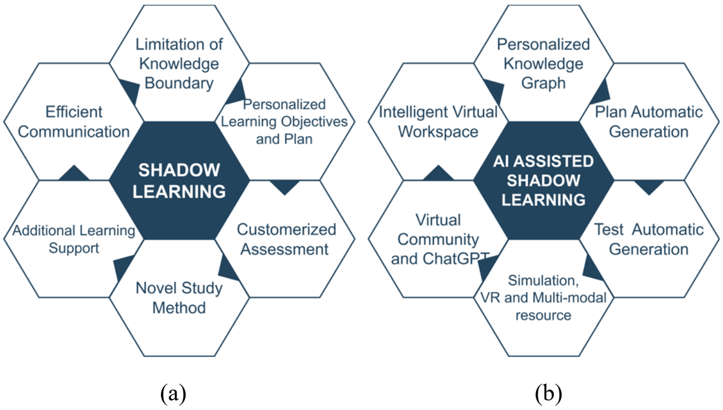

Fig. 1 Shadow Learning Paradigm and AI-Assisted Solutions

Figure 1-a describes the shadow learning paradigm's essential elements for cultivating college students' interdisciplinary innovation ability, including the following.

1. Element 1: The knowledge boundary cannot clarify the scope of knowledge related to the project, figure out the internal relationship between the students' knowledge and the interdisciplinary knowledge, and guide the learning path.

2. Element 2: Personalized learning objectives and plans: The traditional instruction paradigm is often unsuitable for shadow learning situations. According to the requirements of project development progress and students' conditions, the shadow learning paradigm needs to customize personalized learning objectives, schedules, and contents to strengthen the learning effect and master relevant knowledge efficiently.

3. Element 3: Customized assessment: At each stage of the traditional instruction process, the supervisor evaluates the student's ability according to the syllabus requirements. However, in the shadow learning process, each student needs to customize personalized assessment according to the actual situation to ensure the implementation of the learning plan, achievement of the learning objectives, and completion of the OBE (Outcome-based Education) closed loop.

4. Element 4: Novel learning methods: Unlike traditional instruction paradigms based on textbook and helicopter teaching, shadow learning requires diverse unusual learning methods, such as mobile learning, blended learning, fragmented learning, etc., to ensure the efficiency of interdisciplinary learning.

5. Element 5: Additional learning support: Depending on their needs, students must obtain adequate help through Internet searches and virtual learning communities.

6. Element 6: Efficient communication: Efficient communication is the basis of interdisciplinary collaborative innovation in R&D teams. Students from different majors need multimodal communication, including text, oral presentations, charts, animations, videos, etc., to demonstrate their thoughts.

Figure 1-b presents the AI-assisted solutions for all elements of the shadow learning paradigm.

1. Element 1: Personalized Knowledge Graph. Through NLP (Natural Language Processing) techniques, knowledge and relationships were automatically extracted from each curriculum's teaching syllabus, teaching schedule, and training scheme. Then, the whole knowledge graph of the project was constructed. According to the subject and grade of each member in the project, diverse regions are divided in the scope of the whole knowledge graph. Finally, the personalized knowledge graph that each project member needs to master is extracted to limit a rational learning boundary. Mao summarized the application of knowledge graph in the teaching process by Chinese education researchers in the past 15 years since 2007 and clarified that knowledge graph is an essential teaching tool [13]. Fettach also investigated the knowledge graph methods and technologies of instructional conception, knowledge management, personalized learning, question answering, and assessment in education. She emphasized that the knowledge graph has attracted more and more attention to improving teaching and employability [14]. Luo tried to use knowledge graphs to carry out knowledge management, helping students establish personalized knowledge hierarchical systems and learning logic to cultivate college students' innovative ability in the learning process of physics [15]. Many scholars have proposed methods to construct knowledge graph for education. For example, Chen developed K12EduKG system to build a knowledge graph for K-12 education subjects automatically [16]. Nair discussed building the knowledge graph for distance education through deep learning technology [17]. Sun proposed a fuzzy knowledge graph system to solve the future personalized needs of intelligent education [18].

2. Element 2: Plan automatic generation. According to the personalized learning boundary of knowledge and assignment of tasks, students' learning objectives, contents, and progress need to be planned automatically. Fiallos generated Intelligent Curriculum semi-automatically via semantic extraction from existing digital learning materials and validated the efficiency of this method [19].

3. Element 3: Test automatic generation: According to customized learning contents and learning plans of students, various assessments are generated and evaluated automatically. Das used NLP technology to analyze the course's key sentences to create questionnaires automatically. Das has also proved the efficiency of his automatic evaluation system through experiments [20].

4. Element 4: Simulation, virtual reality, and multimodal learning. The intelligent simulation system can simulate the operation and principles of knowledge so that students can understand and master complex knowledge efficiently. Multimodal learning also attempts to learn complex knowledge through various channels such as text, sound, image, video, and virtual reality. Ayaz and Ismail emphasize that healthcare simulation will be a crucial technology for the future of Medical Education. At an early stage, Simulation technology was generally used in the military and aviation fields. Due to the lack of clinical education on the COVID-19 pandemic, simulation technology, as an essential supplement, has effectively improved the skills and self-confidence of students [21]. Fowler et al. designed the Mock ECHO training model to care for common and complex diseases through video conferencing networks with an interprofessional team of specialists. Through remote diagnosis and collaboration, the ECHO project provides a platform for interdisciplinary clinician experts to share practical skills and receive feedback through participants and facilitators via a community of practice [22]. Oje et al. analyzed 51 projects of

VR-assisted engineering education and suggested that VR-assisted engineering education should combine pedagogical theory with multimedia design. Educators, practitioners, and designers should develop and optimize VR applications together [23]. Kok et al. studied digital learning tools for radiation oncology education, including the first and second-generation VR and AR technologies, and discussed the matching problem between digital learning methods and teaching content. After that, Kok suggests that digital learning projects combining personalized learning programs with engaging delivery methods will be a significant trend in the next decade [24].

5. Element 5: Virtual community and ChatGPT. Virtual communities on various topics are a critical platform for exchanging information and solutions. They inevitably acquire additional knowledge according to the student's needs without enough guidance. At present, ChatGPT, as an efficient Q&A software, also has an efficient and excellent performance. Dai discussed the challenges and opportunities that ChatGPT and generative AI bring to the teaching and assessment of higher education. It clarified that ChatGPT can drive students' innovation, strengthen students' learning ability, and enrich educational resources [25]. Gill et al. analyzed ChatGPT as a transformative tool in the academic environment, emphasizing that teachers and students must understand its advantages and disadvantages [26].

6. Element 6: Smart virtual workspace. The idea exchange between interdisciplinary students is generally tricky and inefficient, full of misconceptions, missing information, and questions. An intelligent virtual workspace is often an essential collaborative platform for effective interdisciplinary research, including sharing learning resources, discussing research models, and presenting research results. Lau discusses the effect of ubiquitous learning workspace on creative thinking training in tertiary design education. Lau also analyzes how information and communication technologies (ICTs) make ubiquitous eLearning workspaces possible and can be effectively applied to innovative thinking training [27]. Boulanger et al. proposed a multi-strategy workspace to guide the teaching of design courses for structural engineers. It is a multi-strategy tool that helps students make reasonable decisions in complex design tasks through multi-source knowledge support, interactive development mechanisms, and navigable architecture [28].

4 Conclusion

Cultivating college students' innovative ability is the core content of quality education, while interdisciplinary innovation is an essential form of innovation. This paper discusses the shadow learning paradigm for the cultivation of the interdisciplinary innovation ability of college students. The shadow learning model is an essential supplement to the conventional instruction paradigm and an indispensable strategy to cultivate practical innovation ability. This paper analyzes six problems of shadow learning (including knowledge boundary limitation, personalized learning objectives and plans, customized learning effect evaluation, novel learning methods, additional learning support, and effective communication methods) in cultivating college students' innovative abilities. Furthermore, a range of feasible AI-assisted solutions are proposed regarding these six problems of shadow learning.

More knowledge graphs will be constructed for interdisciplinary innovation teams in the following work. Based on the outcome-based education (OBE) principle, the latest natural language processing, generative AI technology, and multimodal simulation technology are introduced into each stage and level of shadow learning to optimize the shadow learning process, effect monitoring, and feedback mechanism. However, education is always one of the driving forces of AI development [29]. I also believe that Artificial General Intelligence (AGI) [29] and Artificial Super Intelligence (ASI) [29] could transform the whole education paradigm in the future.

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