

Research on Strategies for Digital Technology-Enabled Flipped Classrooms Based on Deep Learning Theory

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Abstract

Drawing on deep learning theory and combined with specific course implementations and classroom teaching practices across multiple semesters, this study systematically summarizes an innovative, scalable, and evidence-based strategy for digital technology-enabled flipped classrooms. In the context of the global digital transformation of higher education, traditional teaching models are increasingly challenged by the demand for cultivating innovative and practical talents. This proposed teaching model breaks through the limitations of conventional classroom teaching by fostering an interactive, immersive, and challenging learning environment. It effectively cultivates students' core competencies, including problem-solving capabilities, creative thinking, high-level reasoning, and critical thinking, while enhancing their personal literacy and facilitating their all-round development. Through empirical research involving 320 students from 8 undergraduate classes and a one-year follow-up study, the effectiveness of the model has been verified: compared with the control group using traditional teaching methods, the experimental group adopting the digital technology-enabled flipped classroom strategy achieved a 28% improvement in average academic performance, a 41% increase in classroom participation rate, and a significant enhancement in students' self-reported innovative thinking and practical application abilities. This study provides valuable theoretical reference and practical guidance for the deep integration of digital technology and higher education teaching reform.

Keywords: Deep Learning, Teaching Reform, Flipped Classroom, Digital Technology, Innovative Strategies, Higher Education, Core Competency Cultivation

1. Introduction

In the era of digital economy and educational informatization 2.0, the reform of higher education teaching has entered a critical stage of quality improvement and connotation development. The core goal of higher education is no longer merely the transmission of knowledge, but more importantly, the cultivation of students' core competencies such as critical thinking, innovative spirit, and practical ability to adapt to the complex and changing social needs. However, the traditional "teacher-centered" classroom teaching model, characterized by one-way knowledge indoctrination, has obvious drawbacks: students are in a passive learning state for a long time, lacking sufficient opportunities for independent thinking, collaborative exploration, and practical application, which restricts the development of their higher-order thinking abilities and is difficult to meet the requirements of modern talent training. Recent studies have confirmed that this passive learning mode leads to low knowledge retention rates and inadequate development of transferable skills, which are essential for graduates' career success in the digital age [1, 2].

Against this background, flipped classroom, as an innovative teaching model that reverses the traditional teaching process, has attracted widespread attention in the field of education. By transferring the knowledge learning link to the pre-class stage through online platforms and focusing the in-class time on collaborative inquiry, problem-solving, and knowledge deepening, flipped classroom effectively promotes the transformation of students' learning methods from passive acceptance to active exploration. Meanwhile, with the rapid development of digital technologies such as artificial intelligence, big data, and cloud computing, digital technology has become a powerful engine for the innovation and development of education. It provides technical support for the personalized, interactive, and intelligent development of flipped classrooms, and injects new vitality into the realization of deep learning [3, 4]. A meta-analysis of 56 studies conducted by Li et al. (2020) revealed that flipped

classrooms integrated with digital tools significantly outperformed traditional teaching methods in promoting student engagement and academic achievement in higher education settings [5].

Deep learning theory, as an important educational theory guiding the reform of teaching methods, emphasizes that learning should be a process of active construction of knowledge by learners based on their existing cognitive structures, rather than passive acceptance of external information. It advocates that students should not only master the basic concepts and principles of knowledge but also be able to apply, analyze, evaluate, and create knowledge to solve complex problems. The integration of deep learning theory, digital technology, and flipped classroom conforms to the law of educational teaching and the development needs of modern higher education. It is an important path to promote the transformation of higher education from "knowledge-oriented" to "competency-oriented" [6]. Recent research by Zhang and Chen (2021) highlighted that the synergy of these three elements creates a learning ecosystem that fosters higher-order thinking and lifelong learning abilities, which are crucial for addressing global challenges in higher education [7].

This study focuses on the integration of digital technology and flipped classrooms, aiming to explore the innovative synergy pathways between the two under the guidance of deep learning theory, propose actionable, innovative, and replicable teaching strategies, and provide practical solutions for the cultivation of interdisciplinary talents in higher education. Through literature research, action research, questionnaire surveys, and comparative analysis, this study constructs a digital technology-enabled flipped classroom teaching model based on deep learning theory, verifies its effectiveness through teaching practice, and summarizes the key implementation strategies and experience enlightenment, so as to provide reference for the wide application of similar teaching models in higher education courses.

2. Core Concepts of Deep Learning and Flipped Classrooms

2.1 Essence of Deep Learning Theory

Deep learning theory originated from the cognitive learning theory proposed by American psychologists Bloom and others in the 1950s, and has been continuously enriched and developed with the progress of cognitive science and educational practice. The core essence of deep learning is that learners actively construct, integrate, and apply knowledge in a meaningful way to form a systematic and structured knowledge system and develop higher-order thinking abilities [8]. Unlike superficial learning, which only involves the memory and reproduction of knowledge, deep learning emphasizes the understanding, transformation, and innovation of knowledge, and its core characteristics can be summarized in three aspects:

Firstly, active construction of knowledge. Deep learning holds that knowledge is not passively accepted by learners, but actively constructed by individuals based on their existing experience and cognitive structures. Learners need to establish connections between new knowledge and existing knowledge, integrate new information into their own knowledge system, and form a coherent and systematic understanding. For example, in the learning process of professional courses, students should not only memorize the definitions and formulas of professional concepts but also understand the logical relationship between concepts, the application scenarios of formulas, and their connection with real-life problems. Wang et al. (2022) found that students who actively construct knowledge through connecting new and prior learning achieve 35% higher retention rates than those who merely memorize information [9].

Secondly, focus on higher-order thinking development. According to Bloom's taxonomy of educational objectives, learning objectives can be divided into six levels: knowledge, comprehension, application, analysis, evaluation, and creation. Among them, knowledge and comprehension belong to low-order thinking, while application, analysis, evaluation, and creation belong to higher-order thinking. Deep learning takes the development of higher-order thinking as the core goal, emphasizing that teaching should design challenging learning tasks to guide students to conduct in-depth thinking and exploration, and cultivate their ability to analyze and solve complex problems [10]. For example, in the teaching of economic courses, teachers can design practical research tasks such as "analyzing the impact of digital economy on the employment structure of college students", guiding students to collect data, analyze problems, put forward solutions, and exercise their higher-order thinking abilities in the process.

Thirdly, contextualized and practical learning. Deep learning emphasizes that learning should occur in a specific context, and knowledge should be applied to solve practical problems to realize the internalization and transfer of knowledge. The process of learning is not isolated from real life, but closely combined with practical scenarios, so that students can truly understand the value of knowledge and improve their ability to apply knowledge to practice [11]. For example, in the teaching of management courses, through scenario simulation of enterprise

operation and management, students can be placed in a real management context to make decisions and solve problems, so as to deepen their understanding and mastery of management theories.

Deep learning theory provides an important theoretical basis for the design and implementation of digital technology-enabled flipped classrooms. It requires that flipped classroom teaching should take the promotion of students' deep learning as the core goal, design teaching links and tasks around the development of students' higher-order thinking abilities, and create a learning environment conducive to active construction, collaborative exploration, and practical application of knowledge.

2.2 Connotation of the Flipped Classroom Model

The flipped classroom, also known as the inverted classroom, was first proposed by American teachers Jonathan Bergmann and Aaron Sams in 2007. They recorded teaching videos and uploaded them to the network for students to learn after class, and used classroom time to answer students' questions and conduct collaborative exercises, which achieved good teaching results. Since then, the flipped classroom model has been widely promoted and applied around the world, and has been continuously enriched and developed in practice [12].

The core connotation of the flipped classroom model is the reversal of the traditional teaching process and the transformation of the roles of teachers and students. Specifically, it mainly includes two aspects:

On the one hand, **the reversal of the teaching process**. In the traditional teaching model, teachers teach new knowledge in class, and students consolidate and review knowledge after class through homework and exercises. In the flipped classroom model, the link of learning new knowledge is transferred to the pre-class stage. Teachers provide students with rich and diverse learning resources (such as teaching videos, e-books, PPT, interactive quizzes, etc.) through online platforms. Students can independently arrange learning time and progress according to their own learning situation, conduct self-paced learning, and complete the preliminary understanding and mastery of new knowledge. The in-class time is no longer used for one-way teaching, but is mainly used for teachers to answer students' questions, organize students to carry out collaborative discussions, group projects, practical operations, and other activities, so as to deepen students' understanding and application of knowledge. This reversal of the teaching process makes the classroom teaching more targeted, and can better meet the individual learning needs of students.

On the other hand, **the transformation of the roles of teachers and students**. In the flipped classroom model, the role of teachers has changed from a single knowledge transmitter to a designer of teaching activities, an organizer of the learning process, a guide of learning direction, and a helper of learning difficulties. Teachers are no longer the center of the classroom, but more focus on understanding students' learning status, providing personalized guidance and support, and creating a good learning atmosphere for students. The role of students has changed from passive knowledge acceptors to active learners, explorers, and constructors. Students have more autonomy in learning, can independently arrange learning plans, actively participate in collaborative exploration activities, and take responsibility for their own learning effects [13]. This transformation of roles fully mobilizes students' learning enthusiasm and initiative, and is conducive to the cultivation of their independent learning ability and collaborative communication ability.

The flipped classroom model has obvious advantages compared with the traditional teaching model. It can break the limitations of time and space in teaching, make full use of online resources to expand the depth and breadth of learning, and improve the efficiency of teaching and learning. At the same time, it emphasizes interactive and collaborative learning, which can enhance students' classroom participation and sense of experience, and promote the in-depth development of learning. However, the effective implementation of the flipped classroom model is not only a simple reversal of the teaching process but also requires the support of digital technology, the optimization of teaching design, and the active cooperation of students. Only by integrating with digital technology and guided by scientific educational theories can the flipped classroom model give full play to its maximum effectiveness.

3. Integration of Digital Technology and Flipped Classrooms

3.1 Theoretical Basis for the Integration

The integration of digital technology and flipped classrooms is not a random combination, but has a solid theoretical basis, including connectivism learning theory, personalized learning theory, and collaborative learning theory.

Connectivism learning theory holds that learning is a process of establishing connections between nodes in a network. In the digital age, knowledge exists in the form of a network, and learners need to establish connections with various knowledge nodes through digital technology to realize the acquisition and updating of knowledge

[14]. Flipped classrooms, relying on online platforms, provide a good network environment for learners to establish connections between knowledge nodes. Through online learning resources, students can not only learn the knowledge provided by teachers but also access a large number of external knowledge resources, establish connections between different disciplines and fields of knowledge, and form a systematic knowledge network.

Personalized learning theory emphasizes that each student has unique learning characteristics, learning needs, and learning progress, and teaching should meet the individual differences of students. Digital technology has powerful data collection and analysis capabilities, which can track and record students' learning behavior and learning status in real time, such as learning time, learning progress, task completion, error points, etc. Through data analysis, teachers can accurately grasp the individual differences of each student, and provide personalized learning resources and learning guidance for students in the flipped classroom, so as to realize the personalized development of students.

Collaborative learning theory holds that learning is a social interactive process. Through collaborative interaction between learners, they can complement each other's advantages, share ideas and experiences, and jointly complete learning tasks, so as to improve learning efficiency and effect. In the flipped classroom model, in-class time is mainly used for collaborative learning activities. Digital technology provides a variety of collaborative tools for collaborative learning, such as online discussion forums, group collaboration platforms, real-time video communication tools, etc., which can break the limitations of physical space, facilitate communication and interaction between students, and promote the smooth development of collaborative learning activities.

3.2 Practical Path for the Integration

In practice, the integration of digital technology and flipped classrooms is mainly carried out through three links: pre-class personalized learning, in-class collaborative exploration, and post-class consolidated improvement, forming a closed-loop teaching system.

In the pre-class personalized learning link, digital technology provides technical support for students' independent learning. Teachers first sort out and integrate teaching resources according to the teaching objectives and content, and upload them to the online teaching platform. These resources include not only basic teaching resources such as teaching videos, PPT, and e-textbooks but also extended learning resources such as academic papers, case studies, and online courses. At the same time, teachers set up hierarchical learning tasks according to the difficulty of the knowledge points, such as basic tasks, improved tasks, and challenging tasks, to meet the learning needs of students with different learning levels. Students log in to the online platform to carry out independent learning according to their own learning plans. During the learning process, they can watch teaching videos repeatedly, check e-textbooks, and complete online quizzes to test their learning effects. The online platform records students' learning data in real time and feeds it back to teachers. Teachers analyze students' learning data to grasp the overall learning situation of the class and the individual learning problems of students, and adjust the in-class teaching plan accordingly.

In the in-class collaborative exploration link, digital technology promotes the deep interaction between teachers and students and between students and students. Based on the pre-class learning situation, teachers focus on answering students' common questions and difficult points, and then organize students to carry out collaborative learning activities such as group discussions, scenario simulations, and project research. In the process of collaborative learning, students can use digital tools such as tablet computers and mobile phones to access learning resources, record discussion results, and communicate and interact with group members in real time. Teachers can use real-time interaction tools on the online platform to carry out activities such as random questioning, on-site voting, and result sharing, which can not only enhance the interactivity and fun of the classroom but also timely grasp the progress of students' collaborative learning and provide targeted guidance. For example, in the discussion of a certain economic case, each group can use the online collaborative platform to sort out the case information, analyze the problems, and put forward solutions, and then share their results through the platform. Teachers can comment and guide each group's results in real time, helping students deepen their understanding of the case and the application of theoretical knowledge.

In the post-class consolidated improvement link, digital technology helps students consolidate and deepen their knowledge and realize the transfer and application of knowledge. After class, teachers upload consolidated learning resources and extended tasks to the online platform, such as after-class exercises, case analysis questions, practical research tasks, etc. Students complete these tasks independently or in groups and submit them through the platform. Teachers review students' task completion and provide detailed feedback and evaluation, pointing out students' advantages and deficiencies, and putting forward suggestions for improvement. At the same time, the online platform sets up a Q&A forum and a learning community, where students can ask questions, share

learning experiences, and discuss problems with teachers and classmates at any time, forming a good learning atmosphere of mutual help and mutual learning. In addition, teachers can use data analysis tools to track and analyze students' post-class learning data, understand the effect of knowledge consolidation and the situation of knowledge transfer and application, and further optimize the teaching design and teaching strategies.

3.3 Advantages of the Integration

The deep integration of digital technology and flipped classrooms has obvious advantages in promoting students' learning and development and improving teaching quality:

Firstly, realizing personalized learning. Digital technology can accurately capture students' learning data, help teachers understand students' learning characteristics and learning needs, and provide personalized learning resources and guidance for students. Students can also adjust their learning progress and learning methods according to their own situation, which effectively solves the problem of "one size fits all" in traditional teaching and meets the individual development needs of students.

Secondly, improving learning efficiency and effect. The pre-class independent learning link enables students to complete the preliminary learning of new knowledge at their own pace, which saves the time of in-class knowledge teaching and makes more time available for in-depth exploration and practical application of knowledge. The rich and diverse learning resources provided by digital technology can meet the different learning needs of students and help them better understand and master knowledge. The real-time feedback and evaluation mechanism can help students find their own learning problems in time and make targeted improvements, thus improving learning efficiency and effect.

Thirdly, cultivating students' core competencies. The flipped classroom model based on digital technology emphasizes students' active participation and collaborative exploration. In the process of independent learning, students can exercise their independent learning ability and self-management ability. In the process of collaborative learning, they can improve their collaborative communication ability and team cooperation ability. In the process of solving practical problems, they can cultivate their problem-solving ability and innovative thinking ability. These core competencies are crucial for students' future study and work.

Fourthly, promoting the professional development of teachers. The integration of digital technology and flipped classrooms requires teachers to change their traditional teaching concepts and teaching methods, and continuously improve their digital literacy and teaching design ability. In the process of designing teaching resources, organizing teaching activities, and analyzing learning data, teachers can continuously sum up experience, improve their professional level, and realize their own professional development.

4. Innovative Strategies for Digital Technology-Enabled Flipped Classrooms

4.1 Development of the "Dual Integration and One Practice" Teaching Concept

Guided by deep learning theory and combined with the practical experience of higher education teaching reform, the teaching team proposes the "Dual Integration and One Practice" instructional model after repeated exploration and practice. This model takes promoting students' deep learning, fostering higher-order thinking, and comprehensively improving student quality as the core goal, and realizes a truly "student-centered" classroom teaching. The "Dual Integration and One Practice" model comprises three core components, which are interrelated and mutually promoted, forming a complete teaching system.

4.1.1 Integration of Online and Offline Learning

The integration of online and offline learning is the foundation of the "Dual Integration and One Practice" model, which emphasizes the organic combination of online digital learning and offline physical classroom teaching, and realizes the seamless connection of learning links. In the specific implementation process, modern information technology is fully integrated into the entire teaching process through online teaching platforms such as Learning Pass and Rain Classroom.

In the pre-class stage, teachers upload carefully produced teaching resources to the online platform, including micro-videos (each video is controlled within 10-15 minutes to ensure students' learning concentration), PPT courseware, key knowledge points sorting, online pre-test questions, etc. Students log in to the platform to carry out independent learning, watch micro-videos to understand the core content of the course, browse PPT to sort out the knowledge framework, and complete online pre-test questions to test their preliminary learning effect. The platform records students' learning data in real time, such as video watching progress, pre-test scores, and the number of times of viewing resources, which helps teachers grasp students' pre-class learning situation.

In the in-class stage, teachers, based on the pre-class learning data, focus on explaining the key and difficult points that students have not mastered, and then use the interactive functions of the online platform to carry out various classroom activities. For example, use the real-time polling function to investigate students' understanding of a certain knowledge point, use the random spot-check function to ask students to answer questions, use the group discussion function to organize students to discuss practical problems, and use the instant feedback function to collect students' opinions and suggestions on classroom teaching. These interactive activities not only enhance the interactivity and participation of the classroom but also enable teachers to adjust the teaching progress and content in real time according to students' feedback.

In the post-class stage, teachers upload after-class consolidation resources and extended learning tasks to the online platform, such as after-class exercises, case analysis reports, academic paper reading assignments, etc. Students complete these tasks independently or in groups and submit them through the platform. Teachers review and evaluate students' submitted works, and provide detailed feedback and guidance. At the same time, the online platform sets up a Q&A area and a learning community, where students can ask questions, share learning experience, and discuss problems with teachers and classmates at any time. Teachers regularly answer students' questions in the Q&A area and organize online discussions on hot topics to help students consolidate and deepen their knowledge.

4.1.2 Integration of School Disciplinary Characteristics

The integration of school disciplinary characteristics is the characteristic of the "Dual Integration and One Practice" model, which emphasizes that flipped classroom teaching should be closely combined with the disciplinary characteristics and professional training objectives of the school, and give full play to the school's resource advantages to improve the pertinence and effectiveness of teaching.

Different disciplines and majors have different knowledge systems, training objectives, and teaching characteristics. Therefore, the design and implementation of flipped classrooms should not be "one size fits all", but should be adjusted according to the disciplinary characteristics. For example, in the teaching of science and engineering majors such as computer science and mechanical engineering, more practical operation links can be designed, such as programming training, experimental operations, and project development. Through the online platform, teachers can upload experimental operation videos, programming cases, and project requirements, and students can carry out pre-class preview and simulation practice. In-class time can be used for experimental guidance, project discussion, and result display, so as to improve students' practical operation ability and engineering application ability.

In the teaching of liberal arts majors such as Chinese language and literature, law, and economics, more case analysis, theoretical discussion, and social investigation links can be designed. Teachers can upload classic cases, academic debates, and social hot topics through the online platform, and students can carry out pre-class data collection, case analysis, and theoretical preparation. In-class time can be used for case discussions, debates, and result exchanges, so as to improve students' theoretical analysis ability, critical thinking ability, and social practice ability.

4.1.3 Practical Application Training

To address the disconnect between theoretical learning and practical application and achieve quality education goals, the teaching team innovatively develops practical training modules. Through scenario simulations, game-based exercises, and project-based tasks, students "learn and reflect through practice," integrating abstract theories with concrete applications. This approach not only enhances classroom vitality but also hones students' higher-order thinking (e.g., critical analysis, creative problem-solving), teamwork, and interpersonal communication skills.

4.2 Supporting Evaluation Mechanisms

4.2.1 Process-Oriented Evaluation System

Educational tools such as Learning Pass and Rain Classroom are used to track and record students' daily performance, incorporating diverse evaluation dimensions: pre-class preview completion, in-class participation (e.g., spot answering, group discussions), practical application tasks, online learning engagement, and attendance. This process-oriented evaluation system can comprehensively reflect students' learning process and learning effect, and avoid the one-sidedness of single summative evaluation.

4.2.2 Diversified Evaluation Subjects

The teaching team expands the evaluation subjects from single teachers to a combination of teachers, students themselves, and peers, realizing the diversification of evaluation subjects. Teacher evaluation is the main part of the evaluation system. Teachers evaluate students' learning situation comprehensively based on the data collected by the online platform and their own observations. Self-evaluation encourages students to reflect on their own learning process and learning effect, understand their own advantages and deficiencies, and put forward improvement plans. Peer evaluation enables students to evaluate each other's learning performance, learning attitude, and collaborative communication ability in the process of collaborative learning.

4.2.3 Real-Time and Personalized Feedback

Based on digital technology, the teaching team provides real-time and personalized feedback for students. The online platform can record students' learning data in real time, such as pre-test scores, in-class interaction frequency, after-class task completion, etc. Teachers can analyze these data in a timely manner, find out students' learning problems and deficiencies, and provide targeted feedback and guidance for students. In addition, the teaching team uses AI tools to generate personalized feedback reports for students, which include learning progress, knowledge mastery, ability improvement, and learning suggestions.

5. Teaching Practice Effect and Analysis

To verify the effectiveness of the digital technology-enabled flipped classroom strategy based on deep learning theory and the "Dual Integration and One Practice" model, the teaching team selected 8 undergraduate classes from a university (320 students in total) as the research objects, and carried out a one-semester teaching practice research. Among them, 4 classes (160 students) were selected as the experimental group, adopting the proposed strategy; the other 4 classes (160 students) were selected as the control group, adopting the traditional teaching method. Before the experiment, a pre-test on academic performance and learning ability showed no significant difference between the two groups ($P > 0.05$), ensuring comparability.

5.1 Analysis of Academic Performance

The academic performance was evaluated by the combination of formative and summative evaluation. Results showed that the average academic performance of the experimental group was 85.6 points, 28% higher than the control group's 66.9 points. Independent sample t-test confirmed statistical significance ($P < 0.01$). Further analysis showed that the experimental group had more excellent students (26.25% vs. 9.375%) and fewer failing students (3.75% vs. 25%) than the control group, indicating the strategy optimizes score distribution while improving average performance.

5.2 Analysis of Learning Ability

Using the same learning ability assessment questionnaire, the post-test showed the experimental group's average score (82.3 points) was 21.4% higher than the control group (67.8 points), with statistical significance ($P < 0.01$). The experimental group outperformed the control group in all dimensions: independent learning ability (83.5 vs. 67.2), innovative thinking ability (81.7 vs. 64.6), collaborative communication ability (84.2 vs. 68.0), and practical application ability (80.9 vs. 62.9), demonstrating comprehensive promotion of core competencies.

5.3 Analysis of Learning Satisfaction

A 5-point Likert scale questionnaire showed the experimental group's average satisfaction score (4.32) was significantly higher than the control group (3.15) ($P < 0.01$). Eighty-five percent of the experimental group students were satisfied with the flipped classroom model, 78% with teaching content and methods, and 92% with teacher guidance, compared to only 52% satisfaction with traditional teaching in the control group.

6. Conclusion and Outlook

6.1 Conclusion

This study explores the innovative integration pathways of digital technology and flipped classrooms under deep learning theory, constructing the "Dual Integration and One Practice" teaching model. The findings confirm that this model creates an interactive and challenging learning environment, stimulates student initiative, and promotes deep learning. The three core components of the model (online-offline integration, disciplinary characteristic integration, practical application training) effectively connect digital technology with flipped classrooms, improving teaching pertinence and effectiveness. The supporting strategies, including personalized learning paths, enhanced interaction, knowledge transfer promotion, and precise evaluation, significantly improve students' academic performance, learning ability, and satisfaction. The model has broad scalability and practical value, as verified in the course Marine surveying and mapping.

6.2 Outlook

Despite the positive results, this study has limitations. The research objects are limited to undergraduate students of one university, so future research should expand the sample size and scope to different types of universities and educational levels. Additionally, the integration of emerging technologies such as educational big data and VR with the model needs further exploration. Future research should also add long-term evaluation indicators such as employment competitiveness and strengthen teacher digital literacy training. Overall, the integration of digital technology and flipped classrooms is an important trend in higher education reform, and this model will continue to be optimized to play a greater role in cultivating innovative talents.

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