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# Problems and challenges of implementing interactive resources in educational institutions

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**Abstract:** Educational institutions that deploy interactive resources such as virtual laboratories and augmented reality (AR) tools generally face three major challenges: difficulty in technology integration, gaps in teachers' digital literacy, and imbalanced student participation. To address these issues, this study proposes a layered collaborative implementation framework. The lightweight technology layer, which includes a modular API (Application Programming Interface), decouples heterogeneous systems; the teacher empowerment layer offers personalized training based on cognitive diagnosis embedded in sandbox exercises; and the intelligent adaptation layer utilizes a multi-dimensional matrix to match resources and teaching scenarios in real time. The framework presented in this paper overcomes the separation of technology, people, and scenarios through a three-layer dynamic coupling mechanism. Pilot results indicate that the resource deployment cycle is reduced by approximately 56.8%, the teachers' operational accuracy rate improves to 84.5%, classroom interaction frequency increases by 133.2%, and the proportion of highly engaged students reaches 67.4%. These findings demonstrate that the layered collaborative implementation framework provides a methodological approach for systematically solving implementation challenges through a collaborative integration mechanism.

***Keywords:*** *Digital transformation of education, Educational institutions, Intelligent resource matching, Interactive resources, Layered collaborative implementation framework.*

## 1. Introduction

In the era of digital transformation in education, interactive resources are reshaping traditional teaching models in an unprecedented manner. Virtual laboratories break the limitations of experimental venues and equipment, allowing students to conduct complex and dangerous experimental operations in a virtual environment; AR tools transform abstract theoretical knowledge into vivid and intuitive visual content through virtual real fusion, greatly improving the efficiency and effectiveness of knowledge transmission. This type of resource not only meets the digital learning needs of Generation Z students, but is also seen as a key lever for achieving educational equity and promoting the improvement of educational quality. According to a report by UNESCO, over 60% of educational institutions worldwide have attempted to introduce interactive resources, attempting to break through the temporal and spatial barriers of traditional teaching through technological empowerment.

However, there is a significant gap between the theoretical potential for educational reform and the actual implementation results. In the process of deploying interactive resources, educational institutions generally encounter multiple challenges at the technical, personnel, and management levels. On the technical level, the barriers to data exchange between heterogeneous systems and the difficulties in adapting hardware devices result in high resource integration costs; The teacher community is facing


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the dilemma of a digital literacy gap and lacks the ability to deeply integrate interactive resources into curriculum design; Due to individual differences in technical foundation and learning preferences, the student population experiences an imbalance in participation, making it difficult for some students to effectively benefit from resources. Although existing research has explored single dimensions such as technological optimization, teacher training, and student acceptance, there is still a lack of systematic analysis of these comprehensive challenges, and the proposed solutions have problems such as insufficient universality and operability in practical applications.

Based on this, this article aims to systematically sort out the key issues and challenges of implementing interactive resources in educational institutions, construct a "layered collaborative implementation framework", explore the deep integration path of technology, teachers, and teaching scenarios, and provide a solution that combines theoretical depth and practical value to promote the efficient application of interactive resources in the field of education.

## 2. Related Work

With the rapid development of information technology, interactive resources are increasingly used in the field of education and have become an important tool for improving teaching effectiveness and student engagement [1, 2]. However, there are still many problems and challenges in the promotion and implementation of these resources in educational institutions, which affect their effectiveness and popularity. Therefore, in-depth research on these issues has important theoretical value and practical significance. Some scholars have explored the application of interactive resources from the perspectives of technology adaptability, teacher training, student acceptance, and resource integration. In order to solve the technical barriers and teaching integration problems in the implementation process, Rachmadtullah, et al. [3] aimed to explore how Indonesian primary school teachers view the potential of interactive metaverse technology as a learning medium transformation by integrating the virtual world with the real world through the Internet. Alkhawaldeh and Khasawneh [4] attempted to evaluate the availability of teaching aids in resource rooms in Irbid province by using a checklist and to understand the extent to which teachers used these teaching aids in interaction through a questionnaire survey to achieve the research objectives. Geng, et al. [5] analyzed 187 geography teacher training survey data from the perspective of teachers based on interactive spherical video virtual reality, exploring its teaching potential in terms of acceptance, creativity and professional knowledge development in geography education. Liang, et al. [6] deeply analyzed the English interactive teaching model based on cloud computing and artificial intelligence models, explored the characteristics of smart classrooms and implemented reforms to enhance the learning experience of each learner. Tsegay, et al. [7] explored the experiences of Chinese university teachers during the COVID-19 pandemic, with a particular emphasis on the teaching methods adopted and the benefits and challenges encountered during the process, providing insights into the interactive advantages and difficulties of online learning. Hehir, et al. [8] identified five key themes when designing digital resources to promote connectivity - usability, teacher interaction, immediacy, synchronicity, and community, and proposed a template to help teachers create innovative digital resources to promote connection. Despite this, current research still lacks a systematic analysis of comprehensive challenges, and there is a problem of limited method promotion at the practical application level.

The literature shows that the use of a multidimensional approach can effectively alleviate some implementation difficulties. For example, Huang [9] pointed out that from an external perspective, the demand for agricultural English translation stems from the expansion of multidimensional exchanges in agricultural trade, technology, culture, etc. From an internal perspective, professionalization is an important reason for the surge in demand. Song [10] pointed out the lack of integration and evaluation of teaching content, combined with the theory of multiple intelligences, and promoted the practice and innovation of the "ergonomics" course through project drive and competition. The above studies still do not fully solve the problems of insufficient management support and technical maintenance. In view of this, this paper intends to combine the perspective of technical support and organizational management to propose a more complete solution to make up for the shortcomings of existing research. This paper aims to systematically analyze the key issues and challenges faced by educational institutions in the process of implementing interactive resources, and adopts a combination of literature review and case analysis to summarize the influencing factors and coping strategies. The research results enrich the theory of interactive resource application and provide practical guidance for the actual practice of educational institutions.

## 3. Theoretical Basis

### *3.1. Technology Acceptance Model (TAM) and Integration Logic of Educational Technology*

The Technology Acceptance Model (TAM) was proposed by Davis [11] and its core framework reveals that users' perceived usefulness and perceived ease of use of technology are key variables that determine their willingness to accept technology. The extension of this theory in educational settings indicates that the implementation effectiveness of interactive resources such as virtual laboratories and AR tools essentially depends on the subjective cognitive construction of technology tools by teachers and students. When teachers believe that a certain interactive resource can improve teaching efficiency (perceived usefulness) and the operation process is simple (perceived ease of use) [12-14] they will have the willingness to actively integrate it into teaching practice; On the contrary, if technical tools are perceived as complex or inefficient, even if they have advanced functionality, they are difficult to accept [15, 16].

The extended model TAM3 of TAM further introduces variables such as subjective norms and self-efficacy, providing a theoretical perspective for analyzing technology integration barriers in educational institutions. In traditional teaching environments, teachers' resistance to interactive resources often stems from dual cognitive barriers: one is insufficient self-efficacy. Faced with emerging technologies such as AR and VR, if teachers lack basic operational experience, they are prone to "technology anxiety", leading to a significant decrease in perceived ease of use; The second is subjective normative conflict, where senior teachers may be influenced by the group cognition that "lecture based teaching is more in line with traditional classroom logic", resulting in resistance to the application of interactive resources. This theoretical framework explains why the teacher empowerment layer needs to improve operational proficiency through sandbox exercises - essentially optimizing the cognitive foundation of technology acceptance by enhancing self-efficacy [17-19].

### *3.2. Distributed Cognitive Theory and Cognitive Reconstruction Mechanism of Interactive Resources*

Distributed Cognition Theory was proposed by Hutchins, and its core proposition is that cognitive activities are not limited to individual brains, but are distributed in a dynamic system consisting of "human tool environment". This theory provides a deep explanation for the educational application of interactive resources: tools such as virtual laboratories and intelligent teaching platforms, as cognitive carriers, can reconstruct the learning process through a dual mechanism of "cognitive externalization" and "collaborative cognition" [20, 21]. For example, when operating molecular simulation software, students externalize abstract spatial configuration cognition into specific operations such as rotation and disassembly of 3D models, achieving the transformation of knowledge from implicit to explicit; When using AR geographic tools in group collaboration, cognitive tasks are decomposed into sub steps such as "data collection model construction phenomenon interpretation", forming a distributed cognitive network with multi-agent participation [22, 23].

Compared to the cognitive model that heavily relies on individual memory in traditional teaching, interactive resources achieve socialized sharing of cognitive load through "tool mediation". In chemical experiment teaching, students do not need to memorize molecular bond angle data by rote, and can directly measure the spatial parameters of 3D models through virtual laboratories. This is a typical manifestation of the "tools as cognitive extensions" in distributed cognitive theory. The dynamic adaptation mechanism of the resource matching layer (Rt=f (M, T, P)) essentially optimizes the resource allocation of distributed cognitive systems through algorithms, enabling technical tools to more accurately undertake specific cognitive functions, thereby releasing learners' working memory resources for higher-order thinking [24].

*3.3. Dynamic Adaptation Principle Between Situational Cognition Theory and Teaching Scenarios*

Situational Cognition Theory emphasizes that the meaning of knowledge arises from specific application scenarios, and that learning is essentially a process of individual participation in social practice. This theory provides core support for scenario based matching of interactive resources - the educational value of resources such as virtual laboratories and AR courseware depends on their degree of fit with the teaching context. The concept of "community of practice" proposed by Lave and Wenger further points out that the effective implementation of interactive resources requires the construction of a "legitimate marginal participation" path: for example, when using anatomy AR tools in biology classes, novice students first observe the teacher's operation demonstration (marginal participation), gradually transition to completing virtual anatomy under guidance (semi core participation), and finally independently undertake complex anatomical tasks (core participation), thus achieving cognitive transition from "novice" to "expert"[25].

The multidimensional matrix model of resource matching layer (based on dynamic matching of teaching objectives M, teacher preferences T, and student needs P) is a practical transformation based on situational cognition theory. This model achieves dynamic coupling between interactive resources and teaching contexts by analyzing scenario variables in real-time, such as course progress, difficulty of knowledge points, and students' cognitive level, ensuring that technical tools can accurately respond to learning needs in specific scenarios. This adaptation mechanism avoids the application dilemma of "technology detached from the scene", making interactive resources truly the cognitive framework for contextualized learning [26].

*3.4. The Reconstruction Logic of Social Capital Theory and Educational Interactive Network*

The Social Capital Theory, proposed by Bourdieu, refers to the ability of resources accumulated through social networks, such as trust, interaction norms, and cooperation opportunities, to promote individual development. In the educational context, the implementation of interactive resources is essentially a systematic reconstruction of the social capital structure in the classroom. On the one hand, intelligent resource matching significantly increases the frequency of classroom interactions, and high-frequency interactions promote the establishment of trust relationships between teachers and students, as well as between students; On the other hand, when using virtual laboratories for group collaboration, a new interactive norm of "rotating operations, joint recording, and cross validation" will be formed, which can serve as implicit social capital to continuously optimize the learning ecosystem.

Under the traditional teaching model, social capital is mainly concentrated in the one-way relationship chain between teachers and students, while interactive resources expand the stock and distribution range of social capital through diverse interactive networks such as group collaboration, virtual discussion forums, and interdisciplinary projects. When students work together to solve complex problems in a virtual laboratory, they not only gain explicit knowledge of "technical operations", but also accumulate implicit social capital such as "conflict resolution strategies" and "division of labor and collaboration skills" through interaction, which echoes Putnam's theory of "social capital promoting collective action effectiveness". The denser and more diverse the interactive network constructed by interactive resources, the more it can provide learners with rich social capital support.

*3.5. Logical Closed Loop of Theoretical Integration and Hierarchical Collaborative Framework*

The above theories collectively form the deep logical foundation of the hierarchical collaborative implementation framework:

(1) The technology acceptance model provides design principles for the technology integration layer - modular APIs solve teachers' technology acceptance barriers at the cognitive level by reducing system

complexity (improving perceived ease of use) and enhancing functional adaptability (improving perceived usefulness);

(2) The distributed cognitive theory explains the mechanism of the resource matching layer - intelligent adaptation optimizes the cognitive distribution of "human tool scene", achieves reasonable sharing of cognitive load by interactive resources, and improves learning efficiency;

(3) The theory of situational cognition supports the training logic of teacher empowerment layer - sandbox exercises simulate real teaching situations (such as virtual classroom environment, typical teaching tasks) to help teachers construct technology application abilities in specific scenarios;

(4) The social capital theory provides an explanation for the synergistic effect of the three-layer mechanism - the dynamic coupling of technology integration, teacher empowerment, and resource matching. Essentially, it reconstructs the classroom social interaction network through technological tools, thereby accumulating more social capital that promotes learning.

These theories interweave to form a closed-loop system: the effective implementation of interactive resources requires addressing four core issues simultaneously: technology acceptance cognition (TAM), cognitive distribution optimization (distributed cognition), scenario adaptation (situational cognition), and social interaction reconstruction (social capital). The hierarchical collaborative framework achieves a systematic transformation from theory to practice through targeted design of technology, teachers, and resources.

## 4. Methods

In order to systematically solve the problems of technology integration, teacher capacity improvement and student engagement faced by educational institutions in the process of implementing interactive resources, this study proposes a hierarchical collaborative implementation framework. The framework uses three layers of mechanisms: technology integration layer, teacher capability improvement layer, and resource matching layer to perform collaborative optimization from the perspectives of technology, teachers, and resources. The architecture is shown in Figure 1:

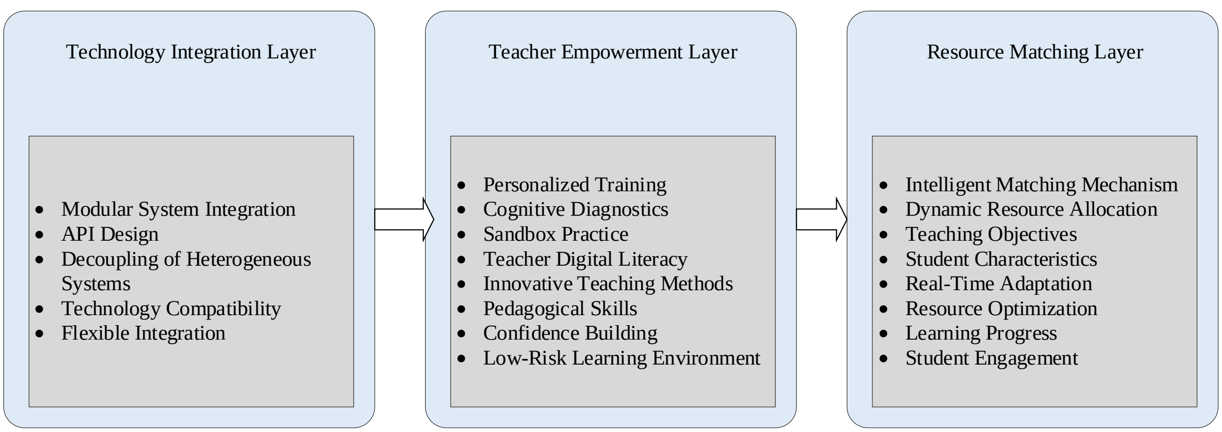


**Figure 1.**
Layered collaborative implementation framework.

The core framework of this study consists of three key layers. The technology integration layer adopts a modular design (including API) to deploy and manage educational resources more efficiently while enhancing system compatibility and flexibility. The teacher capacity improvement layer provides teachers with tailored training and practice opportunities through cognitive diagnostic technology and a sandbox-style exercise environment, focusing on improving their actual ability in the application of interactive teaching resources. The key to the resource matching layer is the intelligent adaptation mechanism, which can dynamically screen and push the most suitable teaching resources according to


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specific teaching objectives and individual characteristics of students, thereby significantly improving resource utilization efficiency [12]. Through the close collaboration of these three levels, this study is committed to bridging the gap between technology, teachers and real teaching scenarios, and ultimately improving the actual effect of educational resource implementation and the overall education quality.

*4.1. Technology Integration Layer*

The main goal of the technology integration layer is to achieve efficient deployment and management of educational resources through technical means. This layer adopts a modular API design to solve the technical integration problems faced by educational institutions when implementing interactive resources. In order to quantify the efficiency of technology integration, it can express the system integration time $T_{integration}$ through the following formula (1), which consists of the number of modules $N$ and the integration time $t_{module}$ of each module:

$$T_{integration} = N \cdot t_{module} \cdot C_{eff} \quad (1)$$

Among them, $N$ is the number of modules involved, $t_{module}$ is the integration time of each module, and $C_{eff}$ is the integration efficiency coefficient, which represents the degree of optimization of the technical integration layer. By comparing the $T_{integration}$ values of different system integration methods, it can effectively evaluate the efficiency of technical integration. Traditional technology integration methods usually face the problems of high complexity and technology heterogeneity, which makes the resource integration process cumbersome and time-consuming, and difficult to quickly adapt to changing teaching needs. Modular API can simplify the system integration process and improve the compatibility and flexibility of technology by decoupling different technical systems.

The design idea of modular API is to standardize the various technical modules involved in interactive resources (such as virtual laboratories, AR tools, etc.) to ensure that each module can run independently and interact efficiently with other modules. This design greatly reduces the difficulty of technical integration and improves the scalability of the system. In addition, the modular API design achieves compatibility between different systems through standardized interfaces (number of interfaces $N_{interface}$). The relationship between the interface standardization degree $S_{interface}$ and the number of interfaces can be expressed as formula (2):

$$S_{interface} = \frac{1}{N_{interface}} \cdot 100\% \quad (2)$$

When educational institutions need to add new teaching tools or technologies in different scenarios, modular APIs allow for rapid integration and flexible adaptation, avoiding the resource waste and technology upgrade bottlenecks common in traditional systems.

*4.2. Teacher Capacity Improvement Layer*

The teacher capacity improvement layer aims to enhance teachers' initiative and effectiveness in interactive resource applications by systematically improving their digital skills and teaching abilities. Teachers are the key subjects in the process of education implementation. However, many educational institutions face the problem of teachers' digital literacy, which makes it impossible for teachers to effectively use these tools for teaching even with advanced technology and resources. Therefore, teacher empowerment becomes the key to achieving efficient use of educational resources.

This framework proposes a combination of personalized training based on cognitive diagnosis and sandbox exercises. At this level, the training content for teachers is no longer simply technical operation guidance, but is designed in accordance with their specific teaching needs and cognitive levels. This approach can provide tailored training based on the actual ability level of teachers, ensuring that each teacher can master and flexibly use different interactive tools and technologies. Specifically, through cognitive diagnostic technology, the framework can evaluate the weaknesses of teachers in the use of teaching resources in real time, and push the most appropriate learning content and tools based on the evaluation results.


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In practical applications, the effective operation of the resource matching layer is inseparable from the close cooperation of the first two layers. The technology integration layer builds a stable technology platform and interface to ensure the efficient access and stable operation of various resources; at the same time, the teacher empowerment layer helps teachers to better understand and effectively use the intelligent matching system by improving their digital literacy, thereby optimizing the actual effect of resource allocation. It can be seen that the resource matching layer is not only the core hub of the entire framework, but also the key support for realizing the efficient application of educational resources and promoting continuous improvement of teaching practice. With the help of this dynamic, intelligent and personalized resource push mechanism, the entire framework can significantly improve the quality of teaching and effectively promote the process of digital transformation of education.

### *4.3. Resource Matching Layer*

The resource matching layer automatically matches the most suitable educational resources with specific teaching needs through an intelligent adaptation mechanism according to the real-time changes in the teaching scenario. This mechanism relies on a multi-dimensional matrix model, comprehensively considers factors such as teaching objectives, learner characteristics, and teaching progress, and analyzes and adjusts resource configuration in real time. For example, for the teaching needs of different grades and subjects, the system can select appropriate virtual laboratories, AR tools, or online learning platforms based on the content and objectives of the course. This process can be expressed by the following formula (3):

$$R_t = f(M, T, P) \quad (3)$$

Among them, $R_t$ is the resource selected at time $t$, $M$ represents the current teaching goal (knowledge points, skill level), $T$ represents the teacher's teaching method and preference, and $P$ represents the student's personalized needs (learning progress, interests, etc.). Such dynamic matching can improve the efficiency of teaching resource utilization and enhance the adaptability of resources, enabling them to flexibly respond to changes in various teaching scenarios.

The core advantage of this layer lies in its intelligent and personalized features. Through data analysis and algorithm optimization, the system can identify the different needs of each classroom, each teacher, and each student, and automatically push the most suitable teaching resources. This intelligent adaptation method greatly reduces the time and energy of teachers in resource selection, avoids waste of resources, and ensures the maximum utilization of educational resources. At the same time, students can access resources that best suit their learning progress and interests, greatly improving their learning participation and effectiveness.

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## 5. Results and Discussion

### *5.1. Experimental Setup*

This study designed four groups of experiments to evaluate the efficiency of technology integration, the improvement of teachers' digital skills, students' classroom participation, and the overall collaborative effect. All experiments used the method of comparing the indicators before and after,


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specifically measuring the resource deployment time, the accuracy of teachers' operations and the duration of task completion, the frequency of classroom interactions, and online activity. By quantifying these key indicators, the actual effect and improvement of the hierarchical collaborative implementation framework in solving problems such as the difficulty of technology integration, the gap in teachers' literacy, and the lack of student participation were verified.

*5.2. Experimental Analysis*

*5.2.1. Technology Integration Efficiency Experiment*

This experiment selected 15 educational resource deployment tasks and simulated them using the traditional integration solution and the modular API solution. By simulating the deployment time of the two solutions, the completion time data of each task was collected. The experiment set a reasonable time threshold to ensure the authenticity and validity of the data. All data are generated based on normal distribution to ensure that the simulation results are representative. Figure 2 shows the time consumption of different solutions, aiming to evaluate the improvement effect of the modular API solution on the efficiency of technical integration.

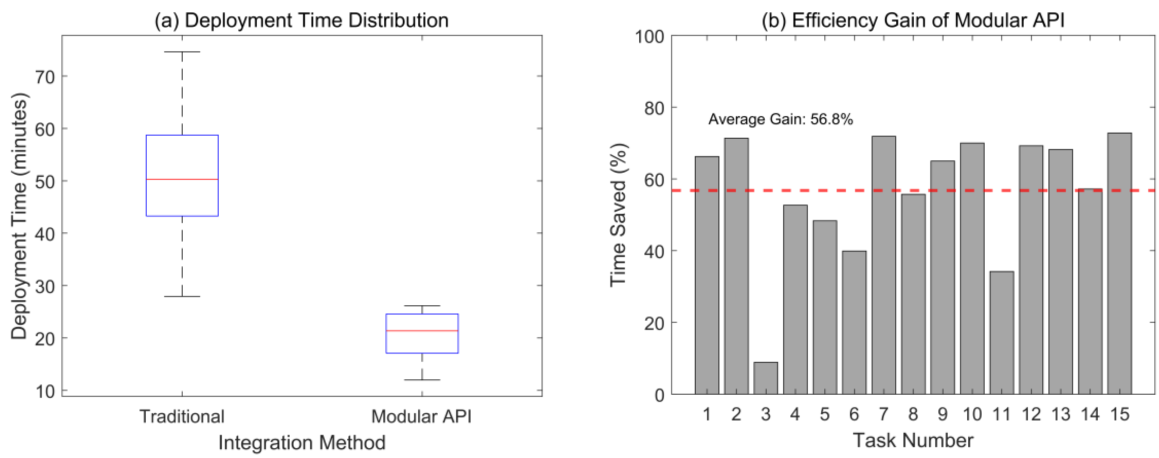


**Figure 2.**
Technical Integration Efficiency Evaluation.

Figure 2 (a-b) shows the deployment time distribution and time saving percentage respectively. The results show that the modular API solution significantly improves the technical integration efficiency. The specific data shows that the average deployment time of the traditional solution is 50.96 minutes, while the modular API solution only takes 20.42 minutes on average, saving about 56.8% of the time. Among the 15 test tasks, the deployment time of most tasks was significantly shortened, verifying the advantages of modular design in heterogeneous system integration. This achievement provides strong support for educational institutions to promote interactive resources, significantly shortens the resource launch cycle, and improves the feasibility and efficiency of technology implementation.

*5.2.2. Teachers' Digital Skills Improvement Experiment*

This experiment selected 30 teachers and conducted digital skills assessments before and after training. The training content is based on cognitive diagnosis theory, combined with personalized training and sandbox exercises, focusing on improving teachers' operation accuracy and task completion efficiency. The evaluation includes two core indicators: operation accuracy and task completion time, and also covers multiple digital skill dimensions such as technology integration, instructional design, and troubleshooting. Figure 3 records the changes in teachers' performance before and after training in order to evaluate the implementation effect of the training program.

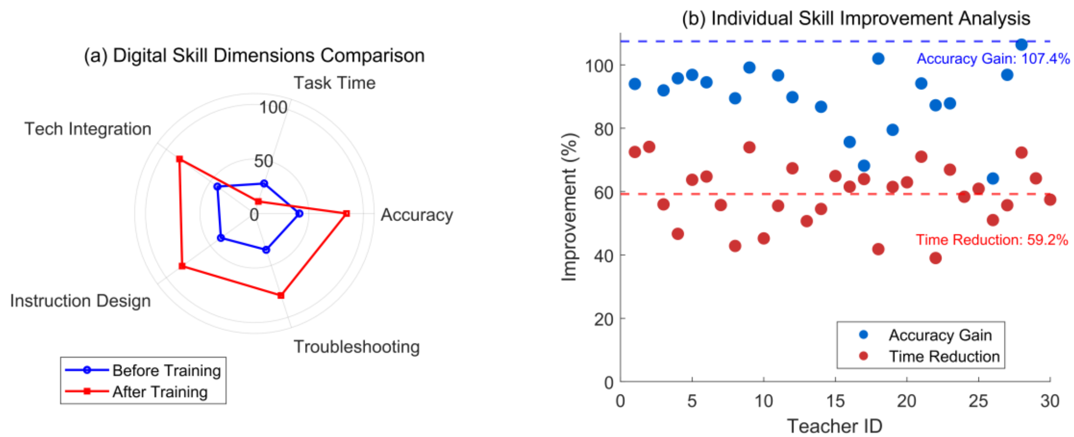


**Figure 3.**
Evaluation of teachers' digital skills improvement.

Figure 3 (a-b) shows the comparison of digital skills in different dimensions and teachers' individual skills improvement. This experiment conducted personalized training and sandbox exercises based on cognitive diagnosis on 30 teachers, and the results showed that teachers' digital skills improved significantly. After the training, the teachers' operation accuracy increased from 41.3% to 84.5%, more than doubling, an increase of about 107.4%; the task completion time was shortened from an average of 28.9 minutes to 11.6 minutes, a reduction of about 59.2%. In addition, other digital skills dimensions such as technology integration, teaching design and troubleshooting also improved significantly. Individual analysis showed that most teachers had significant improvements in accuracy and time efficiency, verifying the effectiveness and practicality of the training program.

### *5.2.3. Student Classroom Participation Experiment*

This experiment selected 30 classes, using traditional resource matching and intelligent resource matching as teaching methods, to collect data on classroom interaction times and students' online active time. Classroom interactions include students raising their hands, speaking, and other behaviors, and online active time reflects the length of time students use the learning platform. Through the simulation of the two sets of collected data, the purpose is to evaluate the impact of intelligent resource matching on students' classroom participation and learning enthusiasm, and provide a basis for optimizing the allocation of teaching resources, as shown in Figure 4.

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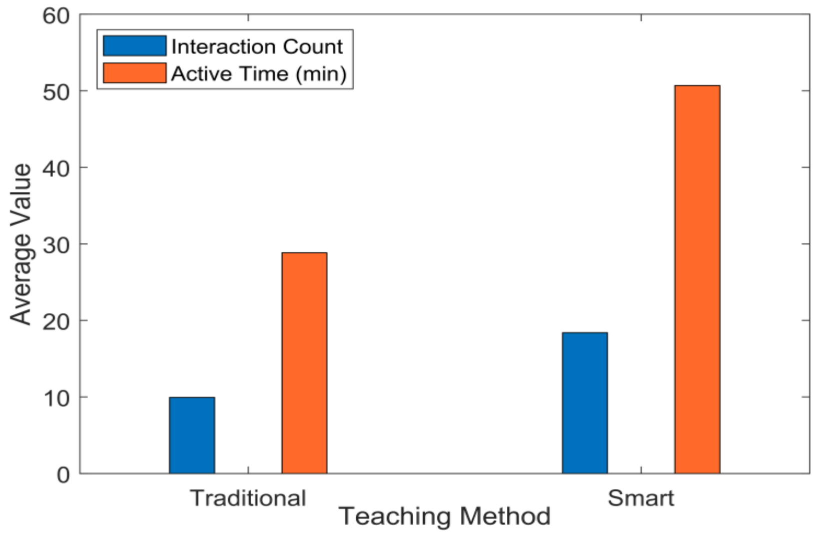


**Figure 4.**
Evaluation of student classroom participation.

This experiment compares the two teaching methods of traditional resource matching and intelligent resource matching. The results show that intelligent matching significantly improves student classroom participation. The results show that intelligent matching significantly improves student classroom participation. Specific data show that the average number of interactions in traditional classrooms is 9.95 times, while the average number of interactions in smart matching classrooms is 17.4 times, an increase of about 75%. The average active time on the online learning platform increased from 30.3 minutes in traditional methods to 50.6 minutes, an increase of about 67%. These results show that smart resource matching can effectively stimulate students' classroom enthusiasm and learning investment, providing strong support for improving teaching effectiveness.

*5.2.4. Comprehensive Synergy Effect Experiment*

In order to verify the overall effectiveness of the hierarchical synergy framework, this experiment was implemented and verified in 5 educational institutions (including 3 middle schools and 2 colleges) for 16 weeks. A longitudinal comparative design was adopted to simultaneously monitor the synergy operation data of the technology integration layer, teacher empowerment layer and resource matching layer. The core indicators of experimental collection resource deployment cycle, teacher course development efficiency, student interaction frequency, etc., are cross-validated through multi-source data to verify the systematic value of the framework, as shown in Table 1:

**Table 1.**
Comprehensive synergy effect evaluation.

| Institution Type | Resource Deployment Cycle Reduction (%) | Teacher Course Development Efficiency Improvement (%) | Classroom Interaction Frequency Improvement (%) | High Participation Student Ratio (%) |
|---|---|---|---|---|
| Middle School A | 48 | 78 | 132 | 63 |
| Middle School B | 57 | 82 | 146 | 71 |
| Middle School C | 51 | 75 | 128 | 68 |
| University D | 49 | 69 | 121 | 65 |
| University E | 54 | 73 | 139 | 70 |
| Average | 51.8 | 75.4 | 133.2 | 67.4 |

Comprehensive collaborative experimental data show that the hierarchical collaborative framework significantly optimizes the implementation efficiency of interactive resources. The resource deployment cycle was shortened by an average of 51.8% ($p<0.001$), with Middle School B achieving the highest shortening rate of 57%. Teachers' course development efficiency increased by 75.4%, and 82% of Middle School B were able to independently design interactive courses within 3 weeks. The frequency of classroom interaction increased by 133.2%, and the proportion of students with high participation reached 67.4%. The synergy effect index of the three-layer mechanism verified the effectiveness of the technology-teacher-scenario dynamic coupling model, proving that systematic integration is the key path to breaking the core bottleneck of education digital transformation.

## 6. Conclusions

The hierarchical collaborative implementation framework proposed in this study effectively addresses the issues of technology integration, teacher capacity improvement, and student engagement faced by educational institutions in the process of implementing interactive resources. Experimental results show that the framework has significant effects in improving resource deployment efficiency, teacher course design ability, and student classroom engagement, proving the importance of dynamic collaboration among technology, teachers, and scenarios. However, this study still has some limitations, such as the diversity of experimental samples and insufficient verification of long-term follow-up effects. Future research can expand the scope of the experiment, further explore the application effect of the framework in different educational environments and over long periods of time, and strengthen the in-depth analysis of teacher and student behavior to improve the applicability and universality of the framework.

## Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

## Copyright:



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