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Investigating the Impact of Information Technology-enhanced Constructivist Teaching on Engineering Undergraduates Learning and Engagement*

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To better promote the role of traditional constructivist teaching models, this study investigates on the impact of information technology-enhanced constructivist teaching on engineering undergraduates learning and engagement. Firstly, the framework of constructivist teaching theory model based on data analysis is constructed, and the relationship among the constructivist teaching model, teaching activity data and flow experience is explicit. Secondly, a real-time teaching management assisted analysis software is developed by ourselves, which expands the mere management tool to an educational method and integrated application. Finally, a practical study is conducted, and the investigation results show that technology information-enhanced constructivist teaching can improve effectiveness by facilitating flow experiences. In addition, real-time feedback on teaching evaluation is positively correlated with the overall assessment of learning effectiveness.

Keywords: constructivist teaching; information technology-enhanced; engineering education; real-time feedback; flow experience

1. Introduction

The current era of information technology, exemplified by cloud computing, big data, and artificial intelligence, is constantly evolving [1]. "Internet-based education" has emerged as a new form of learning [2], offering unique advantages such as breaking the constraints of time and space, rapid replication and dissemination, and diverse presentation methods. It has become a crucial pillar supporting the creation of a ubiquitous learning environment and enabling lifelong learning for everyone. Notably, during the COVID-19 lockdown period, online education [3] adopted out of necessity became a crucial mode of teaching.

Online education has improved sharing educational resources [4], however colleges and universities offer unique advantages for cultivating students' comprehensive qualities, including a humanistic environment, communication, and institutional constraints. Classroom education remains the primary channel for student education, especially for new engineering talents. As a result, classroom teaching will remain a vital form of organizational teaching activity in colleges and universities for the foreseeable future, regardless of how much online education develops [5].

Despite advances in education technology, traditional classroom teaching still faces challenges such as low efficiency and passive learning. With the rise of online education platforms and the need to adapt to new engineering disciplines and talent cultivation, there is a growing need to reconstruct offline classroom teaching. This has become a critical issue in college teaching reform. Shrout [6] demonstrated that it was necessary to comprehensively utilize psychology and science to complete knowledge construction and broaden perspectives. Vieira [7] proposed a framework for collaborative value modeling to strengthen knowledge construction. Cudney [8] evaluated the impact of teaching methods on student motivation to make the curriculum more valuable. Giorgdze [9] introduced interactive teaching methods that would facilitate the establishment of an active, independent and free person with critical thinking.

Passive acquisition of knowledge in the classroom is no longer the goal of engineering education; instead, abilities such as knowledge compounding, integrative skills, and compound thinking are required. Students' learning literacy determines the effectiveness of teaching and learning. Müller [10] proposed that information technology could intervene in student learning activities by means of educational psychology. Dignath [11] provided a framework about how self-regulated learning can be activated directly through strategy instruction. Graesser [12] suggested that educational psychology is evolving to allow for interventions tailored to individual learners through digital technology.

Learning literacy is a cultivation acquired by training and practice, which includes attention, observation, thinking, application, self-awareness, memory, imagination, creativity, and the development of these abilities requires constructivist teaching to acquire them. This paper is an investigation

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to study the effect of the addition of information technology on the promotion of constructivist teaching. Firstly, the framework of constructivist teaching theory model based on data analysis is constructed, and the relationship among the constructivist teaching model, teaching activity data and flow experience is explicit. Secondly, a real-time teaching management assisted analysis software is developed by ourselves, which expands the mere management tool to an educational method and integrated application. Finally, a practical study is conducted, and the investigation results show that technology information-enhanced constructivist teaching can improve teaching effectiveness by facilitating flow experiences to promote active learning and enhance students' learning literacy.

The contributions of this paper lie in:

(1) To integrate information technology and constructivist teaching in engineering education, a framework of constructivist teaching theory model based on data analysis is proposed.
(2) We have developed a teaching management system, which is designed to improve the teaching interaction ability and realize the improvement of teaching effect through data intelligent decision-making.
(3) We have quantified the role of information technology in students learning and engagement, and the research results show that combination of information technology and constructivist teaching can promote flow experience and have a significant positive correlation with learning effectiveness.

2. Methodology of Theoretical Framework

The teaching approach of information technology empowerment, accompanied by optimized educational psychology, transcends the limitations of traditional extroverted teaching methods that rely solely on information technology or introverted teaching reform models. This approach integrates teaching reform theories with information technology, enhancing the efficient learning experience through educational psychology, promoting student autonomy, improving learning outcomes, and ultimately returning education to its roots. Fig. 1 illustrates the overall structure.

The information technology-enhanced constructivist teaching comprises of several components, including the constructivist teaching mode, Real-time teaching evaluation feedback, and flow experience. The constructivist teaching mode emphasizes teaching reform, which is essentially open constructive teaching environment that includes collaboration and competition.

The intelligent teaching management software leverages digital technology to analyze teaching data and transform the traditional approach of knowledge transfer in education. By incorporating discussion-based, inquiry-based, and task-based learning, the software captures all aspects of classroom teaching and provides comprehensive evaluation of students and analysis of teaching activities. Real-time feedback on learning outcomes promotes independent knowledge construction among students.

With the adjustment of the teaching management assisted analysis system, teachers are better able to help students construct their own learning experiences and become learners and reflectors of knowledge. By participating in collaborative and competitive situations, students can develop critical thinking skills, perception, values, and social responsibility. These qualities are not only essential components of individual learning ability but also necessary qualities for the new engineering disciplines that require well-rounded, character-building, and all-round composite talents.

2.1 Constructivist Teaching

Education and teaching activities revolve around the fundamental components of teaching, learning, and knowledge. In the traditional teaching approach, the primary objective is to impart knowledge and enhance learning efficiency through various teaching methods. Constructivist teaching mode [13] in engineering education has resulted in

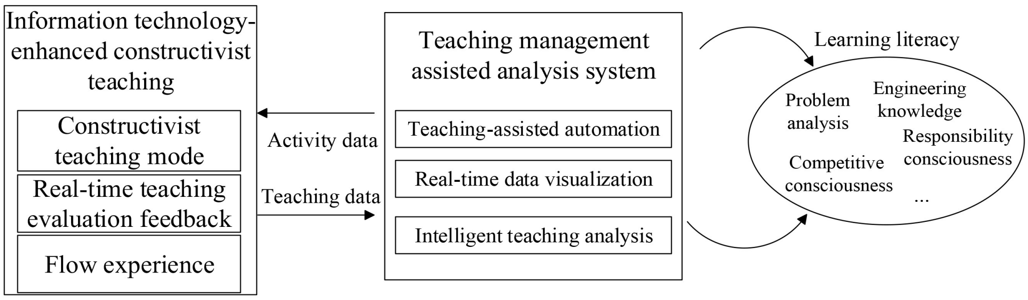


Fig. 1. The framework of constructivist teaching theory model based on data analysis.

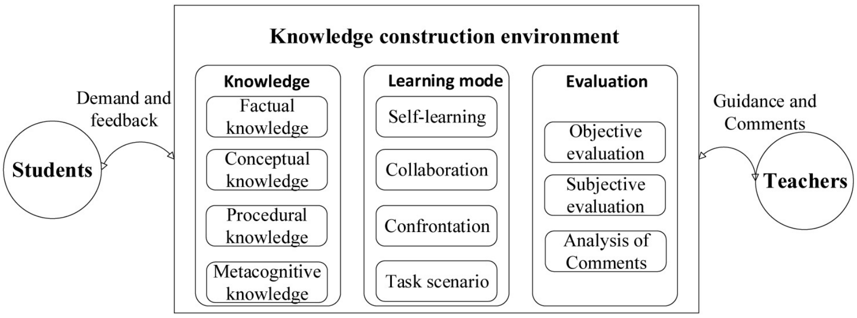


Fig. 2. Knowledge construction environment in competitive mode.

an open teaching environment that unifies the framework of knowledge subjects, learning modes, and evaluation methods. This transformation has facilitated the shift from a traditional one-way teaching link to multiple co-integration. A competitive and collaborative teaching environment guides students to experience a state of flow, thereby stimulating intrinsic learning motivation. By fully leveraging the multi-dimensional role of teaching, learning, and knowledge, a pattern of integrating knowledge and learning through collaborative teaching has been established, as illustrated in Fig. 2.

In open constructivist construction teaching mode, students are encouraged to work together and collaborate to solve problems, rather than being in a confrontational or competitive environment. This approach is intended to foster a sense of teamwork and encourage students to take responsibility for their own learning. The emphasis is on developing skills such as critical thinking, communication, and problem-solving, as well as the ability to work effectively in a team.

2.2 *Teaching Flow Experience*

Flow theory is a significant finding of modern positive psychology [14]. It suggests that individuals, when fully engaged in certain activities or tasks without a significant bias in their perception of their abilities and the difficulty of the task, can enter a state of heightened psychological experience. This state is characterized by relative selflessness and a sense of satisfaction.

Early researchers utilized flow theory to enhance the interactive experience in the field of educational games [15, 16]. By establishing explicit objectives, delivering prompt feedback, directing the user's attention, and choosing appropriate levels of difficulty, programmers could engage students of diverse learning styles and continuously challenge them with tasks that matched their abilities. This approach promotes immersion, allowing users to reach a state of flow, ultimately leading to a satisfying and rewarding experience.

Fig. 3 illustrates the various factors that influence flow experience in a teaching environment. Flow experience is primarily composed of teaching process cognition, learning difficulty cognition, learning motivation, and learning attitude. The cognitive processes involved in teaching and learning, as well as the environmental factors that impact cognitive learning difficulties, directly affect learning motivation, learning attitude, and learning decisions. Digital teaching methods supported by intelligent

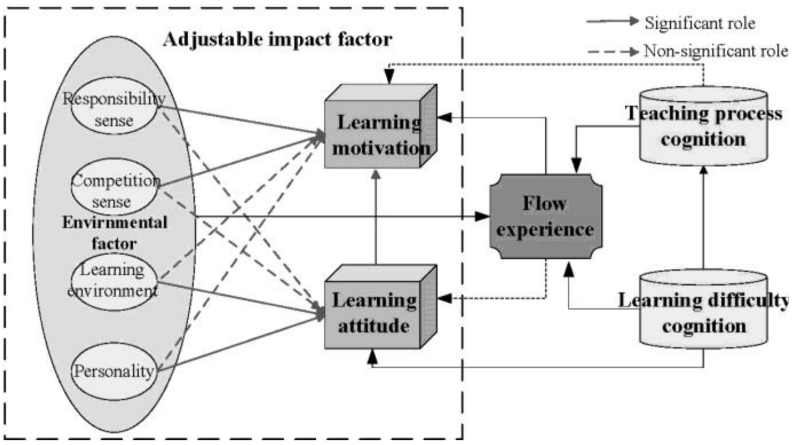
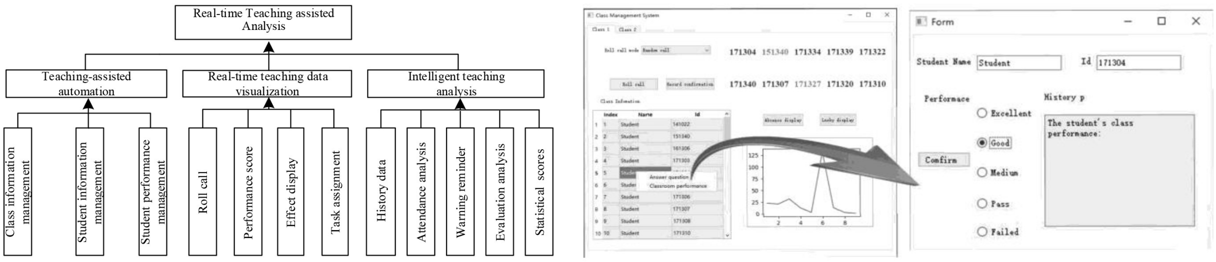


Fig. 3. Impact factor model for teaching flow experience.



(a) System Functions (b) Real-time data recording presentation

Fig. 4. System functions and presentation for real-time teaching management analysis.

information technology can facilitate immediate feedback and evaluation to adjust teaching activities and promote flow experience.

The relationship model between flow experience and teaching activities can be a valuable tool for teachers to support students who struggle with learning. By using this model, teachers can help students find self-confidence in their abilities, set clear learning goals that are achievable, spark their interest in learning, and foster their sense of responsibility for cooperation and competition.

2.3 Real-time Teaching Management Analysis

Based on the impact factor model theory of teaching flow experience, the real-time feedback on teaching evaluation [17] can play a critical role in changing environmental factors, adjusting learning motivation. This feedback is also essential for achieving active flow learning. A real-time teaching management assistant analysis system can provide three main capabilities: teaching-assisted automation, real-time teaching data visualization, and intelligent teaching analysis, as illustrated in Fig. 4(a).

Teaching-assisted automation differs from internet-based teaching platforms. It is primarily designed for use in traditional classroom settings and aims to stimulate student interest in learning through real-time interactive feedback. This approach promotes the occurrence of flow experience and enhances learning motivation.

The intelligent teaching analysis module includes functions such as attendance analysis, performance evaluation, student learning effect evaluation, and early warning for students who may be struggling. By continuously analyzing data in real-time, this module provides a comprehensive analysis of both the teacher's teaching situation and the student's learning situation. This integration of teaching, learning, and evaluation management allows for active adjustments to teaching and personalized learning suggestions. Through this process, students are guided towards active learning and a state of flow experience.

A real-time data visualization module for teaching can enable comprehensive and systematic tracking and recording of the learning process and classroom teaching stages. Based on evaluations and analysis of teaching effectiveness, adjustments to teaching can be made promptly, and personalized learning suggestions can be proposed based on the individual learning needs and conditions of each student.

In the classroom, teachers record real-time data on teaching activities, including the number of questions answered by students and their response performance, as shown in Fig 4(b). Anyone with authorization can access this teaching activity data for future more intelligent teaching analysis.

3. Results and Discussion

Analysis of teaching theory suggests that the teaching approach of empowering students with information technology, coupled with optimizing educational psychology, aligns better with the goal of developing comprehensive literacy skills in engineering education. To confirm the interplay between information technology and introverted flow experience, it is crucial to design teaching experiments. These experiments should examine the impact of real-time teaching management analysis on flow experience, as well as the effect of flow experience on enhancing learning literacy.

Among them, the quantitative analysis assisted by real-time teaching data is based on the real-time evaluation feedback frequency of individual teaching data (as shown in Fig. 4). Flow experience quantification is carried out in six dimensions, such as attention control, balance between challenge and ability, controllable goal, immediate feedback of action, and immersion, as shown in Table 1. The flow experience evaluation can be obtained from the five Likert scale test questionnaire in Appendix, with a total of 20 questions. The total score of flow experience is the sum of the scores of each dimension. The higher the score, the higher the flow experience. To simplify the model, it can be

Table 1. Quantitative evaluation criteria for flow experience

Experience factor	Evaluation Criteria	Rating level
Attention	Ability to maintain attention to lectures	0–5
Ability challenge	The task should be challenging enough and adapt to the knowledge structure	0–5
Sense of control	Have a sense of control over their own learning behavior	0–5
Timely feedback	Students receive feedback on learning effects at the right time	0–5
Immersion	Deeply participate in teaching activities and have positive emotions	0–5
Exploratory behavior	Active learning performance	0–5

Table 2. Descriptive statistics of real-time feedback and flow experience

Level	Mean	Std.Deviation	Std.Error	95% confidence interval of mean	
				Lower Bound	Upper Bound
1	70.500	0.707	0.500	64.147	76.853
2	74.000	8.206	4.103	60.943	87.057
3	68.714	14.326	5.415	55.465	81.964
4	81.571	6.106	2.308	75.924	87.219
5	80.167	6.555	2.676	73.288	87.046
6	86.500	2.121	1.500	67.441	105.559
7	89.33=3	2.082	1.202	84.162	94.505
Total	77.774	10.506	1.887	73.921	81.628

considered that the level of comprehensive literacy is directly proportional to the examination evaluation, so the comprehensive literacy is based on the comprehensive evaluation of students in class.

The practical teaching and research study is conducted on the specialized course "Digital Signal Processing" which contains 3 classes with a total of 105 students. Based on theoretical guidance and experimental design, the teaching practice data would be analyzed. Firstly, verify the interaction between real-time teaching data feedback and flow experience. Since the real-time feedback frequency of teaching data is more than two, the experiment adopts single-factor analysis of variance. Table 2 describes the difference between real-time teaching feedback frequency and flow experience.

Table 3 shows the test of homogeneity of variance, showing that $P = 0.198 > 0.05$, indicating homogeneity of variance. This sample meets the conditions of single analysis of variance.

Single ANOVA (Analysis of Variance) is then performed [18], as shown in Table 4. As can be seen,

Table 3. Test of Homogeneity of Variance

Levene statistic	df1	df 2	Sig.
1.575	6	24	0.198

Table 4. Single Factor Analysis of Variance

	Sum of squares	Mean square	F	Sig.
Between Groups	1425.776	237.629	3.024	0.024
Within Groups	1885.643	78.568		
Total	3311.419			

$P = 0.024 < 0.05$, indicating that there is a significant positive correlation between groups, that is, real-time teaching feedback has a significant positive impact on flow experience.

It can be seen that through a complete and systematic tracking and recording of the learning process and stages of classroom teaching, the evaluation and analysis of teaching effects can be realized, and timely teaching adjustments can be made according to different learning conditions of students and personalized learning suggestions can be put forward, so as to constantly guide students to actively learn and enhance their learning qualities.

The top 40% and the bottom 40% of the total score of flow experience are defined as high group and low group respectively. High group participants are regarded as participants with high flow experience and low group as participants with low flow experience. Next, it will be analyzed whether the subjects with high flow experience and low flow experience are related to the comprehensive score of the course.

Pearson correlation analysis is performed on the total score of flow experience and the comprehensive evaluation score, as shown in Table 5. It can be seen from the table that the Pearson correlation coefficient between the flow experience and the comprehensive evaluation result is 0.586, and the P value is less than 0.01, indicating that there is an extremely significant positive correlation between the flow experience level in the teaching process and the comprehensive evaluation results of the students.

As seen from the study results, the real-time evaluation feedback of information technology-

Table 5. Correlation analysis of flow experience and comprehensive evaluation

Variable	Correlation	Flow level	Comprehensive evaluation
Flow level	Pearson correlation	1	0.586
	Sig. (2-tailed)	–	0.001
Comprehensive evaluation	Pearson correlation	0.586	1
	Sig. (2-tailed	0.001	–

enhanced constructivist teaching is significantly positively correlated with the flow experience of students, and there is a very significant positive correlation between the flow experience level and the comprehensive evaluation scores of students. Under the guidance of educational psychology theory, information technology can be used to improve the learning motivation and attitude of students, promote flow experience, providing support for the cultivation of all-round compound talents under the background of new engineering disciplines.

The limitation of this paper is that the current analysis only analyzes the impact of the constructivist teaching using information technology empowerment on the overall student learning effect. In the future, we will use the teaching management data to refine the analysis and establish an artificial intelligence analysis model to support the individualized teaching.

4. Teaching Revelation

4.1 Guide Students to Improve their Learning Literacy

Learning literacy can be seen as the focus of educational reform. Developments in information technology have broken down the current time and space constraints on learning. Teachers can only continue to help students develop a concept of lifelong learning. On the one hand, students are guided to maintain their learning momentum in all situations, and on the other hand, they are guided to understand their cognitive processes, improve their study habits and develop metacognitive skills. Facing the needs of talent development in engineering education, it is necessary to develop students' problem-solving, teamwork, knowledge construction and higher-order thinking skills through teaching data-driven to continuously improve students' learning literacy and help them achieve active learning.

4.2 Promote Teaching Flow Experience

According to research, flow is mnemonic, and the more you train your brain to get in and stay in flow over time and as habits develop, the easier it becomes to get in. Based on this, in the teaching activities, students are guided to find their learning confidence by creating a reasonable context, clarifying and presenting them with learning objectives in accordance with their abilities, maximising their interest in learning and gradually gaining flow, the experience will become a motivation for students to continuously challenge themselves to achieve self-growth. In addition combining information technology and educational psychology, data on students' learning activities can be analyzed in real time to adjust the teaching process and improve specific teaching sessions. At the same time, classroom control allows for the allocation of appropriate cognitively difficult tasks to students at different levels, thus enhancing student attention in the class.

5. Conclusion

To better promote the role of traditional constructivist teaching models, we investigate the method of using information technology to empower constructivist teaching model. Firstly, we give a framework of constructivist teaching theory model based on data analysis, and collect data of teaching activities in real time through self-developed teaching management assisted analysis software. Through practical investigation, it is found that the real-time teaching evaluation feedback brought by using digital technology has a positive impact on teaching effectiveness.

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Appendix

Likert scale test questionnaire (20 questions)

1. The content of the class attracts my attention.
2. I can concentrate in class.
3. I'm not bored with the irrelevant tasks on the exam.
4. I didn't notice the time of get out of class.
5. I can master the knowledge taught by the teacher.
6. I can accurately understand the tasks assigned by the teacher.
7. The difficulty of the questions or discussion is just right for me.
8. I can complete tasks through teacher guidance or cooperation of classmates.
9. I feel the study task is in my control.
10. I can complete the study task in my own way.
11. In the course of teaching, I clearly know the shortcomings.
12. Provide timely feedback on the learning effect during the teaching process.
13. Keeping abreast of learning process data can help increase learning interest.
14. Feedback helps you know the Level.
15. Can receive questions or learning tasks assigned by the teacher.
16. Ignore the surrounding environment in class.
17. Forget about other things in life temporarily while studying.
18. I will try to complete the learning tasks assigned by the teacher.
19. I will think about how to better apply the knowledge taught by the teacher.
20. I will keep trying to learn new knowledge.

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