International Journal of Sociologies and Anthropologies Science Reviews
Volume 4 Issue 3: May-June 2024: ISSN 2985-2730
Website: https://so07.tci-thaijo.org/index.php/IJSASR/index

The Impact of Web Game-Based Teaching Method on the Academic Performance of Students Majoring in Computer Science Department in a Vocational College in Chengdu

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Received 21/03/2024 Revised 29/03/2024 Accepted 20/04/2024

Abstract

Background and Aim: Educational games offer interactive learning experiences that engage students, enhance motivation, and improve learning outcomes. This study compares game-based learning with traditional methods to enhance academic performance among Computer Science students at a vocational college in Chengdu.

Materials and Methods: A mixed-methods design was used to compare the effects of game-based learning and conventional instruction. 103 students were selected via stratified random sampling, with 51 in the control group and 52 in the experimental group. Pre-test and post-test assessments measured learning outcomes across four knowledge types.

Results: Game-based learning significantly improved all knowledge types compared to traditional methods. Post-test scores were notably higher, indicating the effectiveness of game-based teaching. Both mean and t-test analyses supported the superiority of game-based learning.

Conclusion: Implementing web game-based teaching positively impacts academic performance in Computer Science students at a vocational college in Chengdu. This approach significantly enhances learning outcomes across various knowledge types, offering valuable insights for educational program design in computer science.

Keywords: Game-Based Learning, Serious Games, Bloom's Taxonomy of Educational Objectives, Learning Theory of Constructivism, Situated Learning, Teaching Strategies

Introduction

Computer programming education has broad and profound significance. First, programming learning can improve computational thinking skills (Wong & Cheung, 2018). Second, learning programming can cultivate important cognitive skills such as logical thinking, problem-solving ability, and creativity (Çiftci & Bildiren, 2019) Furthermore, individuals with programming expertise possess a significant edge in the employment market, as professions related to programming are highly sought after in the IT sector (Rahhal et al., 2022).

However, programming education is a challenging learning process (Gomes & Mendes, 2007). Novice computer programming learners are frequently hindered by a lack of abstract thinking and logical ability, as well as the difficulty of rapidly mastering specialized programming tools (Cheah, 2020).

Game-based learning (GBL) is an innovative learning approach (Hartt et al., 2020) that has shown multiple advantages. Firstly, it can enhance students' motivation, engagement, and enjoyment (Hartt et al., 2020). Secondly, by providing interactive and hands-on opportunities, it can enhance students' programming skills (Kazimoglu et al., 2012). Additionally, games also contribute to the development of students' teamwork and collaboration skills, improving their overall competency (Laakso et al., 2021). Compared to traditional classroom instruction (TCI), game-based learning contributes to enhanced learning outcomes (Tokac et al., 2019).

In Chinese vocational colleges, there has been relatively limited research on game-based learning in programming education. According to the China National Knowledge Infrastructure (CNKI) database, game-based learning accounts for only 1.13% of vocational education literature, indicating an immature teaching design and evaluation system.

Citation Chen, G., & Li, C. (2024). The Impact of Web Game-Based Teaching Method on the Academic Performance of Students Majoring in Computer Science Department in a Vocational College in Chengdu. International Journal of Sociologies and Anthropologies Science Reviews, 4 (3), 595-608; DOI: https://doi.org/10.60027/ijsasr.2024.4537

In response to the aforementioned situation, this study aims to explore the application and effects of game-based learning methods in programming education in Chinese vocational colleges, as well as to investigate the best implementation strategies. This study utilizes a mixed-methods design to analyze the impact of game-based learning on different learning outcomes, as well as game-based instructional design and assessment strategies. Ultimately, by designing a game-based learning program suitable for Chinese vocational colleges and collecting valid data, the impact and effectiveness of game-based learning methods on different types of learning outcomes will be evaluated.

Objectives

1. To explore the impact of game-based learning strategies on students' factual knowledge (FK), conceptual knowledge (CK), procedural knowledge (PK), and metacognitive knowledge (MK) before and after receiving GBL (Game-based Learning).

2. To explore the impact of game-based learning strategies on students' factual knowledge (FK), conceptual knowledge (CK), procedural knowledge (PK), and metacognitive knowledge (MK) for those who accept GBL compared to those who accept TCI (Traditional Classroom Instruction).

Literature review

Serious games

Serious games are digital games designed for the main purpose of going beyond entertainment (Caserman et al., 2020). They increase the learners' motivation and engagement by impacting their cognitive, emotional, and social domains (Larson, 2019). Serious games have been proven to be an effective training method, based on the fusion of traditional game elements (such as entertainment) into learning (López et al., 2021). Gamification mechanisms allow users to pursue personal goals and choose between different progression paths, while the system adjusts the complexity according to the users' abilities. Social gamification elements enable social comparisons and connect users to support each other towards mutual goals (Krath et al., 2021).

Game-based Learning

Game-based learning (GBL) refers to an educational setting in which the integration of game content and interactive gameplay enhances the acquisition of knowledge and the development of skills (Qian & Clark, 2016). For centuries, games have served as an educational tool, facilitating learning experiences (Dahalan et al., 2024). Game-based learning is recognized for its extensive utilization in enhancing learning across diverse disciplines (Chen et al., 2020). Online gaming is accessible to everyone, offering the potential for broader utilization in classroom settings on a large scale (Alam, 2022). One of the unique characteristics of game-based learning environments is their ability to generate engaging and effective learning experiences (Emerson et al., 2020). The purpose of game-based learning environments is to cultivate elevated levels of learner motivation and engagement, particularly when tackling intricate subject matter (Taub et al., 2020).

Situated Learning

According to the theory of situational learning, there is a correlation between learning and the social context in which it takes place; learning is influenced by activities, environment, and culture (Sentance & Humphreys, 2018). Based on situational cognition, a crucial objective is to offer a learning context that is both contextualized and immersive (Perry, 2021). The utilization of game-based learning represents a promising method to stimulate students' motivation and cognitive engagement in situational learning (Hou, 2022). A game-based learning environment offers a method for university teachers to integrate digital gaming aspects into classrooms successfully, aligning the course content with the gaming objectives by following a series of steps and activities (Emihovich, 2024). The application of immersive games in innovative educational practices holds promise, as the utilization of situational learning pedagogy provides students with an effective experiential learning process (Lau, 2023).

Bloom's taxonomy of educational objectives

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Since the introduction of Bloom's taxonomy in the 1960s, it has been widely applied worldwide and continues to have a significant impact to this day. According to Bloom's taxonomy, knowledge can be classified into four types: factual knowledge (FK), conceptual knowledge (CK), procedural knowledge (PK), and metacognitive knowledge (MK). Factual knowledge refers to individuals' comprehension and retention of facts, data, and specific information (Krathwohl, 2010). Conceptual knowledge refers to individuals' comprehension of concepts, principles, models, theories, and relationships (Krathwohl, 2010). Procedural knowledge refers to the knowledge that individuals possess and can execute specific tasks or apply specific skills (Krathwohl, 2010). Metacognitive knowledge refers to the awareness and understanding of one's cognitive process, state of knowledge, and learning strategies (Krathwohl, 2010).

Previous Research

Chen et al. (2023) developed an innovative game-based Japanese language learning system to assist working professionals in enhancing their language skills through digital education. A study was conducted with 54 Taiwanese employees over two weeks. Participants were randomly assigned to either an experimental group or a control group, with the experimental group using a game-based Japanese language learning system and the control group using a non-game-based system. The research findings indicate that the game-based Japanese language learning system significantly improved learners' engagement (Hamari et al., 2016) in terms of learning behavior, learning performance, learning motivation (Erhel & Jamet, 2013), and immersion experience.

Fernández Galeote et al. (2023) conducted a study investigating the impact of game-based learning and control on learning outcomes related to climate change concepts. The experiment included 105 participants who were randomly assigned to two treatment groups: one using a desktop-screen video game and the other using an immersive virtual reality (VR) version of the same game. A control group was also established, providing text material accompanied by charts. The findings of this study indicate that both game-based approaches were equally effective as traditional instructional materials. Overall, the results indicate a positive impact of games and/or simulations on learning objectives. Researchers identified three learning outcomes when integrating games into the learning process: cognitive, behavioral, and emotional (Vlachopoulos & Makri, 2017).

Yang and Chen (2021) developed an innovative game-based learning system that provides appropriate guidance and feedback to learners. By seamlessly integrating learning strategies into digital games, the system aims to effectively enhance students' academic performance. This approach was implemented in a quasi-experimental mathematics class and yielded positive outcomes. The research findings indicated a significant improvement in students' academic achievements and memory (Covaci et al., 2018). Therefore, this innovative method is considered both potential and effective.

Taub et al. (2020) examined the effectiveness of game-based learning environments in fostering high engagement and motivation among students when learning complex topics. A study was carried out with 138 university students who interacted with the game-based microbiology learning environment named "Crystal Island." Students were randomly assigned to high agency conditions, low agency conditions, or no agency conditions. The findings from the investigation on the influence of students' agency levels on learning, problem-solving, and outcomes indicate that the provision of moderate agency in a game-based learning environment leads to enhanced learning outcomes, problem-solving abilities, and positive effects on outcomes (Alghamdi & Holland, 2017).

Wardoyo et al. (2020) utilized game-based teaching techniques and provided testing assistance to create an engaging and dynamic learning environment for students. A sample of 100 students from the fields of development economics, management, and accounting was selected, and the gain score method was employed to test and analyze the learning outcomes of the experimental group. The study found that game-based learning is effective in improving students' academic achievements. Effective game-based learning meeting modern educational demands is achievable with ample resources, theoretical frameworks, interdisciplinary competencies, and defined objectives (Moeller et al., 2020).

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A novel astronomy-themed board game was developed by Cardinot and Fairfield (2022), and its impact on learning and teaching astronomy topics covered in the new Irish science curriculum was investigated. The study recruited 119 participants from primary schools across Ireland and collected data through feedback questionnaires, systematic observations, and pre-and post-test surveys. The research findings revealed that the astronomy-themed board game significantly improved students' understanding of astronomical concepts and their perception of scientists. Additionally, the game was proven to be a useful learning tool that fosters the development of social skills (Aberson et al., 2016).

Hartt et al. (2020) investigated the effectiveness of game-based learning in planning education and examined gamification's impact on planning students' perceptions of learning, engagement, and teamwork. Traditional lecture-style teaching and game-based teaching were implemented in an undergraduate planning course, and feedback was collected through online surveys and semi-structured interviews. The research findings demonstrated that game-based teaching, compared to traditional lecture-style teaching, generated higher levels of student interest and engagement (Alghamdi & Holland, 2017) and hence was more suitable for planning education.

Conceptual Framework

This study examined the influence of two independent variables, namely GBL and TCI, on the four dependent variables: Factual Knowledge (FK), Conceptual Knowledge (CK), Procedural Knowledge (PK), and Metacognitive Knowledge (MK). Figure 1 displays the conceptual framework illustrating the relationships between these variables.

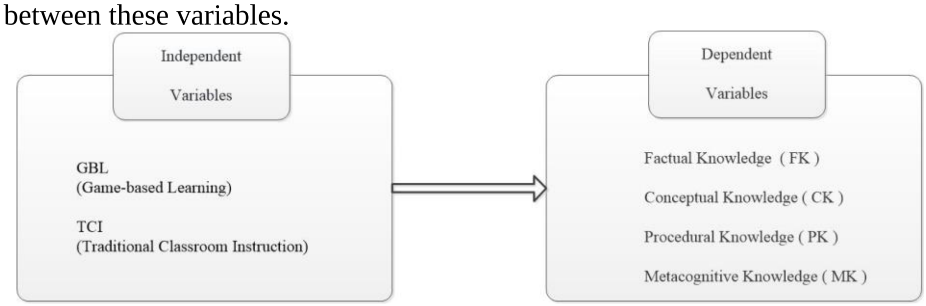

Figure 1 Conceptual Framework

Independent Variables

GBL (Game-based learning): Game-based learning utilizing Code Combat is an instructional methodology that incorporates gaming components into the learning journey. Code Combat is an internet-based platform that enables students to acquire programming knowledge through interactive gameplay.

TCI (Traditional Classroom Instruction): Traditional classroom instruction is a widely recognized teaching strategy. Teachers deliver lectures in a classroom setting, engaging with students using chalkboards and PowerPoint presentations.

Dependent Variables

Factual Knowledge (FK) pertains to learners' comprehension and retention of specific facts and information.

Conceptual Knowledge (CK) encompasses the learner's ability to comprehend and apply abstract concepts, such as principles, theories, and overarching frameworks.

Procedural Knowledge (PK) denotes the learner's mastery and application of specific operations, steps, and skills. In this study, measurements were taken via computer programming tasks to evaluate learners' proficiency and accuracy in practical operations.

Metacognitive Knowledge (MK) refers to learners' comprehension and awareness of their own learning process, strategies, and cognitive monitoring.

Hypotheses

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$H_0$1 There are no differences in factual knowledge (FK) among the students before and after receiving GBL.

H_a1 There are differences in factual knowledge (FK) among the students before and after receiving GBL.

$H_0$2 There are no differences in Factual Knowledge (FK) between students who accept GBL and those who accept TCI.

H_a2 There are differences in Factual Knowledge (FK) between students who accept GBL and those who accept TCI.

$H_0$3 There are no differences in Conceptual Knowledge (CK) among the students before and after receiving GBL.

H_a3 There are differences in Conceptual Knowledge (CK) among the students before and after receiving GBL.

$H_0$4 There are no differences in Conceptual Knowledge (CK) between students who accept GBL and those who accept TCI.

H_a4 There are differences in Conceptual Knowledge (CK) between students who accept GBL and those who accept TCI.

$H_0$5 There are no differences in Procedural Knowledge (PK) among the students before and after receiving GBL.

H_a5 There are differences in Procedural Knowledge (PK) among the students before and after receiving GBL.

$H_0$6 There are no differences in Procedural Knowledge (PK) between students who accept GBL and those who accept TCI.

H_a6 There are differences in Procedural Knowledge (PK) between students who accept GBL and those who accept TCI.

$H_0$7 There are no differences in Metacognitive Knowledge (MK) among the students before and after receiving GBL.

H_a7 There are differences in Metacognitive Knowledge (MK) among the students before and after receiving GBL.

$H_0$8 There are no differences in Metacognitive Knowledge (MK) between students who accept GBL and those who accept TCI.

H_a8 There are differences in Metacognitive Knowledge (MK) between students who accept GBL and those who accept TCI.

Methodology

Research Design

This study employed a mixed-methods design to incorporate Code Combat into the teaching of a programming course, to improve student learning outcomes. We designed an experimental group and a control group, where the experimental group received instruction using the game-based learning (GBL) model, while the control group students received instruction using the traditional classroom instruction (TCI) model. Quantitative data were collected through exams. By comparing the pre-test and post-test scores of students who received instruction from the GBL model and TCI model, we sought to determine whether there was an improvement in the four learning outcomes (FK, CK, PK, and MK), and to validate or refute the research hypothesis. The qualitative analysis of interview data, in connection with the research questions, provides further evidence to support the findings of this study. This research was organized as follows:

1. A test was conducted as a pre-test measurement to assess the students' Factual Knowledge (FK), Conceptual Knowledge (CK), Procedural Knowledge (PK), and Metacognitive Knowledge (MK) scores.

2. In the following 8 weeks, the experimental group students utilized the GBL model to complete their learning tasks, while the control group continued with traditional teaching methods for the same tasks.

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3. After 8 weeks, another test was conducted as a post-test measurement to gauge the students' FK, CK, PK, and MK scores.

4. The scores for FK, CK, PK, and MK were quantitatively analyzed to conclude by comparing the results.

5. Qualitative analysis was performed through group interviews with the experimental group to gather additional evidence.

Population and Sample

The target population of this study consisted of students who were studying programming courses in the computer major at a vocational college in Chengdu. Our target population included three grades, with seven classes in each grade. A stratified random sampling method was employed. Firstly, the target population was divided into three strata based on grade, and then one stratum was randomly selected from these three layers. Subsequently, two classes were randomly selected from the chosen stratum, with one class serving as the control group and the other as the experimental group. Through this sampling process, we obtained a control group comprising 51 students from Sophomore Year Class 1, and an experimental group comprising 52 students from Sophomore Year Class 2. Both groups were taught Python courses by the same teacher.

Research Instruments

The National Computer Rank Examination (NCRE), overseen by the Ministry of Education and organized by the China Computer Federation, is a widely recognized national computer proficiency certification in China.

1. Factual Knowledge Test

Written tests consisting of a set of 10 multiple-choice questions were administered to assess students' factual knowledge (FK). These questions were obtained from the National Computer Rank Examination (NCRE) Question Bank. For example, one question asked, "Which of the following operators is used for exponentiation in Python?", with choices A) **, B) //, C) %, and D) &. The correct answer is A, **.

2. Conceptual Knowledge Test

To assess students' conceptual knowledge (CK), a written exam was administered. The exam included the task of creating a "program flowchart" where students had to demonstrate their understanding and application of abstract programming principles, theories, and frameworks. The questions were sourced from the National Computer Rank Examination (NCRE) Question Bank. An example question and its answer are as follows: "Explain the concept of 'conditional structure'." The answer would be: IF x > 10: PRINT ("x is greater than 10"), ELSE: PRINT("x is less than or equal to 10").

3. Procedural Knowledge Test

Computer programming tasks were assigned to assess students' procedural knowledge (PK). These tasks required students to demonstrate their ability to apply programming concepts and solve practical problems. The tasks were designed based on the National Computer Rank Examination (NCRE) Question Bank. As an example, one task asked students to write a program that calculates the factorial of a given number. The correct solution would involve the use of loops and variables to perform the necessary calculations.

4. Metacognitive Knowledge Test

The Metacognitive Awareness Inventory (Schraw & Dennison, 1994) was employed to assess students' Metacognitive Knowledge (MK). This inventory aided in evaluating students' understanding and awareness of their own learning processes, strategies, and cognitive monitoring.

5. Group Interview

The students in the experimental group were divided into four subgroups, each consisting of 13 students. Interviews were conducted with each of these subgroups to gain insights into their perceptions of game-based teaching. Throughout the interviews, questions were posed, such as: What types of game-based activities would you like to see incorporated into your course?

Validity of the Performance Tests and Interview Questions

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The content validity of the Performance test was assessed by three experts who possess a minimum of ten years of teaching experience in programming courses. The Index of Item Objective Congruence (IOC) was utilized for evaluation. Following the calculation, the IOC values for each test were determined to be 1.00, indicating a high level of consistency between the test content and objectives, thus demonstrating strong content validity.

The interview questionnaire underwent evaluation by three experts, who employed the S-CVI (Content Validity Index) method to calculate the S-CVI/Ave value, resulting in a score of 1. This signifies that the entire questionnaire exhibits sufficient content validity and is well-suited for achieving the research objectives.

Data Collection

The experiment lasted for 8 weeks, during which a preliminary test was conducted for both the experimental and control groups to establish a baseline. Following the implementation of game-based learning, a post-test was carried out to evaluate any alterations in the students' programming skills and learning outcomes. Participation in the pre-test and post-test was mandatory for all students in both groups, with a duration of 120 minutes for each test. The instructor distributed the test papers to the students, who completed them and returned them to the teacher within the designated timeframe. The teacher graded the tests and recorded the results in an Excel spreadsheet. Furthermore, group interviews were conducted with students in the experimental group, and the findings were documented.

Data Analysis

For quantitative data, the predicted and post-test scores of the experimental group and the control group were analyzed using the statistical software SPSS (version 26). Descriptive statistics were used to analyze the mean and standard deviation within each group. Additionally, a paired-sample t-test was conducted to examine if there were significant changes in the scores between the pre-test and post-test within the experimental group. Furthermore, an independent-sample t-test was employed to detect if there were statistically significant differences in the post-test scores between the experimental group and the control group.

For qualitative data, the data from group interviews were recorded and transcribed into text format using the deductive approach (Pandey, 2019). Theme analysis was then conducted to analyze the qualitative data, aiming to identify the main themes regarding participants' perspectives, experiences, and viewpoints on the research question.

Results

Descriptive Statistics

The present study aimed to investigate the effectiveness of using a game-based approach for programming instruction. The research included a control group and an experimental group, and pretests and posttests were administered to assess the student’s performance in four knowledge types: Factual Knowledge (FK), Conceptual Knowledge (CK), Procedural Knowledge (PK), and Metacognitive Knowledge (MK). The results revealed that the experimental group outperformed the control group on the posttests, with higher mean scores (FK: 8.10, CK: 45.40, PK: 42.75, MK: 37.04). This suggests that utilizing a game-based approach for programming instruction has a positive impact on student’s performance across various knowledge types. As shown in Table 1.

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Table 1 Comparison of Pre-test and Post-test Results for Different Variables

Variables	Group	Pre-test			Post-test		
		N	MEAN	S.D.	N	MEAN	S.D.
Factual Knowledge (FK)	Control	51	6.24	2.055	51	7.02	1.393
	Experimental	52	5.79	2.217	52	8.10	1.445
Conceptual Knowledge (CK)	Control	51	35.37	3.026	51	41.88	3.179
	Experimental	52	35.83	2.915	52	45.40	3.877
Procedural Knowledge (PK)	Control	51	33.08	4.947	51	37.06	4.897
	Experimental	52	33.19	4.468	52	42.75	4.769
Metacognitive Knowledge (MK)	Control	51	26.86	10.841	51	25.84	10.341
	Experimental	52	30.00	9.927	52	37.04	9.337

Hypotheses Testing

We conducted a paired-sample t-test to examine the mean difference between the pre-test and post-test of variables in the experimental group. The results are presented in Table 2. For factual knowledge (FK), participants in the experimental group had a mean score of 5.79 with a standard deviation of 2.217 at the pre-test, and a mean score of 8.10 with a standard deviation of 1.445 at the post-test. The paired-sample t-test showed a significant mean difference of -2.308 between the two tests ($p < .001$). Significant differences were also observed in conceptual knowledge (CK), procedural knowledge (PK), and metacognitive knowledge (MK), with mean differences of -9.577 ($p < .001$), -9.558 ($p < .001$), and -7.038 ($p < .001$), respectively. Therefore, based on the results of the paired-sample t-tests, we rejected the null hypotheses $H_0 1$, $H_0 3$, $H_0 5$, and $H_0 7$.

Table 2 T-test for Mean Difference between Pre-test and Post-test of Variables in the experimental group

Experimental Group N=52	Pre-test		Post-test		Mean difference	S.D.	Sig.
	MEAN	S.D.	MEAN	S.D.			
Factual Knowledge (FK)	5.79	2.217	8.10	1.445	-2.308	2.462	.000
Conceptual Knowledge (CK)	35.83	2.915	45.40	3.877	-9.577	4.999	.000
Procedural Knowledge (PK)	33.19	4.468	42.75	4.769	-9.558	6.412	.000
Metacognitive Knowledge (MK)	30.00	9.927	37.04	9.337	-7.038	11,998	.000

As shown in Table 3, we conducted independent samples t-tests to compare the mean differences between the control group and the experimental group for the variables. For factual knowledge (FK), the control group had a post-test mean score of 0.78 with a standard deviation of 2.476, while the experimental group had a post-test mean score of 2.31 with a standard deviation of 2.462. The independent samples t-test revealed a significant mean difference in factual knowledge between the two groups (Mean Difference = -1.523, $p = .002$). For conceptual knowledge (CK), the control group had a post-test mean score of 6.51 with a standard deviation of 4.818, while the experimental group had a post-test mean score of 9.58 with a standard deviation of 4.999. The independent samples t-test showed a significant mean difference in conceptual knowledge between the two groups (Mean Difference = -3.067, $p = .002$). Similarly, for procedural knowledge (PK) and metacognitive knowledge (MK), there were significant mean differences between the control group and the experimental group. The mean difference in procedural knowledge was -5.577 ($p < .001$), and the mean difference in metacognitive knowledge was -8.058 ($p = .003$). All variables had a sample size (N) of 103. Thus, based on the conducted independent samples t-tests, we reject the null hypothesis and conclude that there are significant mean differences between the two groups in terms of various knowledge aspects. Specifically, hypotheses $H_0 2$, $H_0 4$, $H_0 6$, and $H_0 8$ are rejected.

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Table 3 T-test for Means Difference of Variables between the control group and experimental group

Variables	Group	Improvement			Mean Difference	Sig.	N
		N	MEAN	S.D.			
Factual Knowledge (FK)	Control	51	0.78	2.476	-1.523	.002	103
	Experimental	52	2.31	2.462			
Conceptual Knowledge (CK)	Control	51	6.51	4.818	-3.067	.002	103
	Experimental	52	9.58	4.999			
Procedural Knowledge (PK)	Control	51	3.98	7.747	-5.577	.000	103
	Experimental	52	9.56	6.412			
Metacognitive Knowledge (MK)	Control	51	-1.02	14.312	-8.058	.003	103
	Experimental	52	7.04	11.998			

The following table summarizes hypothesis testing results regarding knowledge aspects before and after GBL implementation, as well as between GBL and TCI groups.

Table 4 Summary of Hypothesis testing and results

Hypotheses	Statement	Result after Analysis
H_01	There are no differences in factual knowledge (FK) among the students before and after receiving GBL.	rejected
H_02	There are no differences in Factual Knowledge (FK) between students who accept GBL and those who accept TCI.	rejected
H_03	There are no differences in Conceptual Knowledge (CK) among the students before and after receiving GBL.	rejected
H_04	There are no differences in Conceptual Knowledge (CK) between students who accept GBL and those who accept TCI.	rejected
H_05	There are no differences in Procedural Knowledge (PK) among the students before and after receiving GBL.	rejected
H_06	There are no differences in Procedural Knowledge (PK) between students who accept GBL and those who accept TCI.	rejected
H_07	There are no differences in Metacognitive Knowledge (MK) among the students before and after receiving GBL.	rejected
H_08	There are no differences in Metacognitive Knowledge (MK) between students who accept GBL and those who accept TCI.	rejected

Students' Opinions Towards Game-based Learning

Experimental group students expressed their views on Game-based learning during group interviews, which involved 2 main themes and 10 topics.

In the interview, students were asked about their attitudes and opinions towards game-based learning. When asked if they had played online digital games and whether they believed these games had educational significance, one student mentioned that they had been playing online games since they were young, such as puzzle games and role-playing games. They believed that these games could enhance their logical thinking and problem-solving abilities. Furthermore, when asked if they liked the online digital games provided to them, another student stated that these games were enjoyable and increased their engagement in the course, acknowledging the significant help these games provided in their learning. Finally, when asked about the type of game-based activities they would like to see introduced in the curriculum, the students expressed that they would be delighted if games that could improve spatial imagination and reaction speed were included in their courses.

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The analysis results from the group interviews revealed that students had a positive perception of game-based learning methods. The interview data supported the findings from the previous quantitative analysis, indicating that the instructional design had played a significant role in improving students' learning outcomes.

Discussion and Conclusion

This study utilized a mixed qualitative and quantitative approach to investigate the efficacy of game-based learning in programming education, to enhance student learning outcomes. Drawing from teacher and student surveys, NCRE exam syllabi, and theoretical frameworks such as Situated Learning Theory, Game-based Learning Theory, and Bloom's Taxonomy, instructional methods integrating game-based learning were developed and implemented for the experimental group. Statistical analysis revealed a significant improvement in the experimental group's performance across four types of knowledge between pre-test and post-test assessments compared to the control group, affirming the positive impact of game-based learning on learning outcomes. Additionally, group interviews with the experimental group underscored their favorable disposition towards programming education facilitated by game-based learning.

From the perspective of teaching effectiveness, the advantages of game-based learning can be mainly reflected in the following aspects.

Firstly, game-based learning helps students better understand and memorize factual information. By interacting with tasks and challenges within the game, students learned and applied various concepts, definitions, and rules, enhancing their mastery of factual knowledge (Susilaningsih et al., 2020). Incorporating personalization and collaboration into game-based learning can further enhance the knowledge level of students in higher education (Troussas et al., 2020).

Secondly, game-based learning helped students develop abstract thinking and conceptual understanding. Games often involve complex problems and scenarios, requiring students to solve problems, develop strategies, and make decisions to succeed. This process prompted students to think, analyze, and understand various concepts and their relationships, deepening their understanding and application of conceptual knowledge (Chan et al., 2021).

Furthermore, game-based learning allows students to acquire various processes and skills. Games simulated real-world operations and tasks, requiring students to learn how to control characters, solve problems, and complete missions. Game-based learning can bridge the gap between theoretical and practical knowledge (Szegedine Lengyel, 2020). Through continuous practice and experimentation, students gradually mastered various operational skills and problem-solving methods, improving their proficiency and accuracy in practical tasks. Integrating games into education has the potential to enhance students' motivation and engagement in the learning process, leading to the accumulation of enduring practical knowledge (Videnovik et al., 2023).

Moreover, Game-based learning facilitates the development of metacognitive abilities. Serious games contribute to enhanced cognitive skills, empathy cultivation, and the teaching of new strategies to address bullying and cyberbullying (Calvo-Morata et al., 2020). Game-based learning also has an impact on the memory processes of graphics and colors (Chang et al., 2020). Digital game-based learning has the potential to influence students' creative skills, critical thinking, knowledge transfer, digital experience skills, and positive learning attitudes while providing in-depth and insightful learning opportunities (Behnamnia et al., 2020). In the context of flood combat learning, a serious game package significantly affects students' disaster prevention skills, learning interests, self-awareness, and sense of civic responsibility (Tsai et al., 2020). Acquiring knowledge through game-based teaching enhances students' learning efficiency and helps cultivate their creativity and thinking skills (Liang, 2022).

Additionally, game-based learning has emerged as an innovative instructional technique that can enhance students' motivation, emotional involvement, and enjoyment (Hartt et al., 2020). Utilizing game-based learning can improve students' thinking skills (Behnamnia et al., 2022). Students in game-based

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learning groups demonstrate significantly better performance in content knowledge assessments and report higher self-efficacy (Wang & Zheng, 2020). Research findings indicate that game-based learning has a significant and positive impact on students' engagement and academic achievement (Krouska et al., 2022).

The study unveiled the process and efficacy of game-based learning in programming instruction, along with students' perceptions of learning activities. These findings offer insights into employing games for programming education, benefiting educators in crafting effective learning activities.

Recommendation

Overall, the study demonstrated the significant benefits of implementing a game-based learning model for computer science education in a vocational college in Chengdu. The recommendations stemming from these findings are as follows:

For Students and Educational Enhancement

1. Encourage students to actively engage in web game-based learning activities to enhance their academic performance in computer science.

2. Motivate students to develop a strong interest in utilizing game-based learning methods to improve their understanding and retention of course materials.

For Educators and Curriculum Development

1 Provide training and resources for educators to effectively implement game-based teaching methods in computer science courses.

2 Collaborate with instructional designers to develop interactive and engaging game-based learning modules that align with the curriculum objectives.

For Educational Institutions and Policy Makers

1 Allocate resources and support for the integration of web game-based teaching methods in the computer science department curriculum.

2 Establish policies that promote the use of innovative teaching approaches, such as game-based learning, to enhance student learning outcomes and overall academic performance.

For Future Research and Advancements

1 Conduct longitudinal studies to further investigate the long-term impact of game-based learning on academic performance and student retention rates in computer science programs.

2 Explore the potential of incorporating virtual reality and augmented reality technologies into web game-based teaching methods for enhanced student engagement and learning outcomes.

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