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RESEARCH ARTICLE

Enhancing Project-Based Blended Learning (PJBBL) Model in Algorithm Design: A Comprehensive Needs Analysis

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ABSTRACT

This research explores the potential of Project-Based Learning (PBL) and the Cloud Education Model in Algorithm Design education. Through a multifaceted approach, the study identifies the specific needs of teachers and students when adopting the project-based learning model. In an experimental study, it used the PJBBL model in the domain of algorithm design education. A pre-test and post-test experimental design were used to reach a conclusion. Twenty teachers and 100 BS students were randomly selected from the college for interviews and questionnaire administration, respectively, whereas 66 students were selected through cluster sampling for experimentation. A pre-test-post-test design was used for the experiment, whereas descriptive statistics besides MANOVA were used to analyze the data. The study results indicate that the PJBBL model has shown promising outcomes in enhancing students' algorithm design and analysis capabilities. Integrating real-world projects and blended learning methods has deeply engaged students, fostering a better understanding of algorithmic concepts and their practical application. Teachers' feedback has shed light on effective pedagogical strategies, enabling them to create a conducive learning environment and support students in their algorithmic learning. The research demonstrates the efficacy of the Project-Based Blended Learning (PJBBL) model in Algorithm Design and Analysis education.

INTRODUCTION

In today's rapidly evolving era, Information Technology (IT) plays a pivotal role across various industries. It permeates all aspects of life, works, and learning for diverse groups of people (Zhang et al., 2022). From its early application in scientific research and industry to the widespread use of the internet, IT has entered an unprecedented development phase with the rise of artificial intelligence (AI) (Wang et al., 2023). As a result, higher education institutions have become instrumental in nurturing and cultivating computer talents to meet the demands of this technologically driven landscape (Haleem et al., 2022). Notably, computer science majors have a crucial responsibility to master programming knowledge and skills, ensuring they can adeptly tackle problems using programming languages and develop a strong engineering application mindset (Jung and Lee, 2020).

As a global powerhouse, China is also experiencing an escalating demand for computer talent. According to a report by McKinsey & Company, the country is estimated to require approximately 700,000 to 900,000 new IT professionals annually in the forthcoming years to meet this surging demand (Shi et al., 2016). Particularly with the advent of the AI era, the necessity for high-quality computer engineers has become paramount, as they are entrusted with developing and maintaining intelligent software and devices. Consequently, higher education institutions in China have been tasked with nurturing a pool of high-tech computer engineering talents poised to drive technological innovation.

Within computer engineering, algorithm research is of utmost significance, encompassing various computing models such as parallel computers, distributed computers, probability-based algorithms, and even quantum algorithms (Salim et al., 2023). Due to the broad scope of algorithms and their applicability to diverse problem domains, the teaching content in this area tends to be scattered and specialized. Traditional teaching approaches often focus on imparting the mathematical logic foundation of algorithms separately from their implementation and testing, typically within a single programming language (Bashabsheh et al., 2022).

However, a paradigm shift in computer science education is imperative to address the evolving needs of the IT industry and equip students with the comprehensive skills required for the AI-driven landscape. One innovative approach that has garnered attention is the Project-Based Blended Learning (PJBBL) model, which combines the merits of project-based learning and blended learning methods. This model offers a transformative pedagogical approach, enabling students to engage deeply with algorithm design and analysis in a real-world context while incorporating online and offline learning experiences. This research aims to explore the effectiveness of the Project-Based Blended Learning (PJBBL) model in the context of Algorithm Design education. By conducting a comprehensive needs analysis, this study endeavors to identify the specific requirements of both students and teachers within this innovative educational framework. The research further seeks to assess the impact of PJBBL on teaching and learning management, as well as the enhancement of subject ability and self-learning proficiency for both students and educators. Ultimately, the findings of this study aim to contribute valuable insights into optimizing computer science education and fostering a new generation of adept and adaptable computer engineering talents for the AI era.

Objectives of the study

- To identify learners' and teachers' specific needs and preferences concerning implementing a project-based learning model based on blended learning.
- To develop a comprehensive and effective learning model that integrates project-based learning principles with the blended learning approach specifically tailored for the course.
- To compare the impact of the Project-Based Blended Learning (PJBBL) model on students' engagement and autonomous learning abilities with that of traditional teaching methods.

LITERATURE REVIEW

Project-based learning

Project-Based Learning (PBL) is gaining popularity in education due to its transformative potential for engaging learners and fostering deeper understanding (Chen et al., 2021). It bridges the gap between traditional education and real-world practice by offering authentic learning experiences (Stein and Graham, 2014). PBL is student-centered, emphasizing active Learning and problem-solving skills (Abuhmaid, 2020). Learners tackle real-world projects, developing academic knowledge and 21st-century competencies (Vasiliene-Vasiliauskiene et al., 2020).

Blended Learning complements PBL by combining face-to-face and online instruction (Cheung and Hew, 2011). Online platforms provide flexibility, enabling self-directed Learning. Blended Learning fosters continuous assessment and feedback. The combined benefits of PBL and blended Learning can address challenges in traditional settings, enhancing engagement and motivation.

Developing a Project-Based Blended Learning (PJBBL), model can revolutionize computer science instruction in the context of algorithm design education. PJBBL empowers students to engage with complex problems, collaborate, and apply knowledge practically. Understanding the needs of learners and teachers is crucial to designing effective PJBBL strategies that maximize engagement and enhance autonomous learning (Marantika, 2021). Metacognitive ability and autonomous learning strategies improve learning outcomes.

Exploring PJBBL's potential in algorithm design education has far-reaching implications for preparing students for careers in the IT industry. PJBBL offers a dynamic and interactive learning environment that nurtures curiosity, creativity, and a passion for Learning. PJBBL can shape a new generation of adept and adaptable computer science professionals by aligning educational practices with real-world demands.

Blended learning

Blended Learning, a pedagogical approach integrating face-to-face instruction and online activities, has gained recognition for its potential to enhance learning experiences (Garrison and Kanuka, 2004). It emerged in the 1990s with technology integration to create a cohesive learning environment (Halverson and Graham, 2019). Blended Learning offers flexibility, interactive learning experiences, and data-driven assessment (Zhao,2022).

Effective across educational domains, blended Learning improves outcomes and engagement in K–12 and higher education (Makhdoom et al., 2013). In algorithm design education, blending fosters active Learning, critical thinking, and individualized support (Useche et al., 2022). It overcomes the challenges of limited practice time and facilitates self-paced Learning.

Successful implementation requires alignment with objectives and consideration of digital literacy. Training and support for faculty enhance outcomes. Blended Learning transforms education, creating dynamic and engaging experiences (Zhao, 2022). Algorithm design enriches learning, develops critical skills, and prepares students for the IT industry's demands.

Project-based learning model based on blended Learning

The Project-Based Learning (PBL) model based on blended Learning seamlessly integrates face-to-face project experiences with online learning activities, fostering an engaging learning environment. The step-by-step process includes project design, online Learning, practical projects, reflection, and summarization, ensuring meaningful and authentic learning experiences. Students actively engage in real-world challenges, developing teamwork and communication skills (Boss and Krauss, 2022).

Blended Learning offers flexibility and personalized learning pathways, catering to diverse learning needs. Educators leverage online platforms to track student progress and provide targeted support (Harbour and Denham, 2021). Additionally, technology integration fosters digital literacy and equips students with essential 21st-century skills.

The PBL model based on blended Learning offers a dynamic and comprehensive educational approach. Combining face-to-face and online components creates an enriching and engaging learning environment. Students actively participate, apply knowledge practically, and develop critical skills (Blasco-Arcas et al., 2013). Integrating blended Learning enhances flexibility, personalization, and digital literacy, making it a promising approach for meeting diverse learning needs in the digital age.

Algorithm design and analysis capability

In computer science, algorithm design, and analysis capability are essential skills that equip students with the expertise to tackle complex problem-solving tasks efficiently and effectively (Du et al., 2022). Students must develop competence in various aspects of algorithm knowledge, design, optimization, analysis, and programming implementation to achieve proficiency in this domain.

Firstly, a comprehensive understanding of algorithm knowledge forms the foundation of algorithm design and analysis. Students must master common algorithms and data structures, such as sorting, searching, graph algorithms, tree algorithms, string matching, and dynamic programming. This knowledge enables them to recognize appropriate algorithmic solutions for specific problem characteristics.

Secondly, students should acquire the skill to design algorithms tailored to specific problem requirements. This involves selecting suitable algorithms based on problem attributes and devising efficient algorithm implementations (Minutoli et al., 2020). A well-designed algorithm can significantly impact the overall performance of a solution and lead to optimized outcomes.

Algorithm optimization constitutes the third aspect of algorithm design and analysis. Students need to learn techniques to enhance algorithms, making them faster, more memory-efficient, and better suited to meet specific time and space constraints (Rajabioun, 2011). Optimization skills are particularly crucial in scenarios where performance is critical.

The fourth element pertains to algorithm analysis. Students should be capable of rigorously assessing algorithms' correctness, time complexity, and space complexity. This involves evaluating the efficiency of algorithms under various conditions, including worst-case, average-case, and best-case scenarios (Osaba et al., 2021). Such analysis enables students to make informed decisions about algorithm selection based on the demands of different problem sets.

Lastly, programming implementation skills are indispensable for putting algorithmic concepts into practice. Students should be proficient in using programming languages to implement algorithms and testing, debugging, and optimizing their implementations. Practical programming experience solidifies their understanding and ability to apply algorithms to real-world problems (Osaba et al., 2021).

Recognizing the significance of Algorithm Design and Analysis, universities typically employ various assessment methods to evaluate students' mastery of these skills (Boom et al., 2022). These evaluation methods may include written examinations, problem-solving assignments, coding challenges, and practical projects. By employing diverse assessment techniques, educators can comprehensively gauge students' algorithmic proficiency and identify areas for improvement.

Thus, mastering Algorithm Design and Analysis capabilities is critical for computer science majors. By encompassing algorithm knowledge, design, optimization, analysis, and programming implementation, students can become adept problem solvers equipped to handle diverse challenges in computer science. Evaluating these skills through varied assessment methods ensures that students are well-prepared to navigate the complexities of algorithmic problem-solving and contribute meaningfully to the field.

Related Research

Several research efforts have highlighted the significance of Algorithm Design and Analysis capability and its application in various computer science and engineering fields.

Anwar et al. (2022) emphasized that engineering education, including electronic engineering, plays a crucial role in preparing graduates to navigate the challenges posed by the COVID-19 pandemic and its aftermath. The researchers investigated the application of hybrid learning projects in electronic engineering education courses, focusing on project-based product design and development through hybrid learning. The study explored how blending face-to-face and online learning approaches can enhance students' algorithmic skills and ability to apply algorithms to practical projects in the electronic engineering domain.

Naragund and Handur (2013) emphasized that algorithms form the backbone of computer science and engineering, enabling computers to complete tasks efficiently. Their research delved into applying algorithm design and analysis in real-world scenarios, such as optimizing computer network protocols, data compression techniques, and cryptography algorithms. The study showcased how algorithms are critical in developing efficient and secure computing systems, benefiting various industries and technological advancements.

Wang (2023) studied integrating Project-Based Learning (PBL) and Algorithm Design and Analysis in computer science education. The research aimed to evaluate the impact of PBL on students' algorithmic understanding, problem-solving abilities, and collaboration skills. The findings highlighted that PBL-based approaches enhanced students' motivation, critical thinking, and teamwork, improving their algorithm design capabilities.

Xiang et al. (2019) explored the effectiveness of utilizing visualization techniques in teaching Algorithm Design and Analysis. Their research investigated the use of visual aids, such as flowcharts, diagrams, and animations, to illustrate complex algorithmic concepts and algorithms' execution processes. The study revealed that visualization enhanced students' comprehension and retention of algorithmic principles, making the learning experience more engaging and accessible.

Liu et al. (2017) focused on applying Algorithm Design and Analysis in the context of data analytics and machine learning. Their research explored various algorithms used in data mining, pattern recognition, and predictive modeling. The study demonstrated how algorithm design is fundamental to extracting meaningful insights and knowledge from vast datasets, paving the way for advancements in artificial intelligence and data-driven decision-making.

Collectively, these research efforts underscore the crucial role of Algorithm Design and Analysis capability in computer science and engineering education. From the application of hybrid learning in electronic engineering courses to integrating Project-Based Learning and using visualization techniques, these studies showcase innovative approaches to enhancing students' algorithmic skills and problem-solving abilities. Moreover, applying algorithms in diverse fields like computer networking, data analytics, and artificial intelligence highlights algorithmic knowledge's broad and impactful significance in modern technological advancements. As researchers and educators continue to explore and refine these approaches, the Algorithm Design and Analysis field will remain a cornerstone in shaping the future of computer science and engineering.

The research gap in this area stems from the limited exploration of the PJBBL model in algorithm design education. While PBL and blended learning have been studied independently, their combined potential in computer science instruction remains relatively unexplored. As algorithm design spans many problems and concepts, a comprehensive and cohesive approach integrating project-based and blended learning principles could significantly enhance students' learning experiences and overall outcomes. Hence, investigating the effectiveness of the Project-Based Blended Learning (PJBBL) model in algorithm design education has far-reaching implications for computer science instruction and the development of competent computer engineering talents. By providing students with authentic project experiences and leveraging the benefits of blended learning technologies, PJBBL can transform algorithm design education, equipping learners with practical skills, critical thinking abilities, and adaptability to thrive in the AI-driven landscape.

Conceptual framework

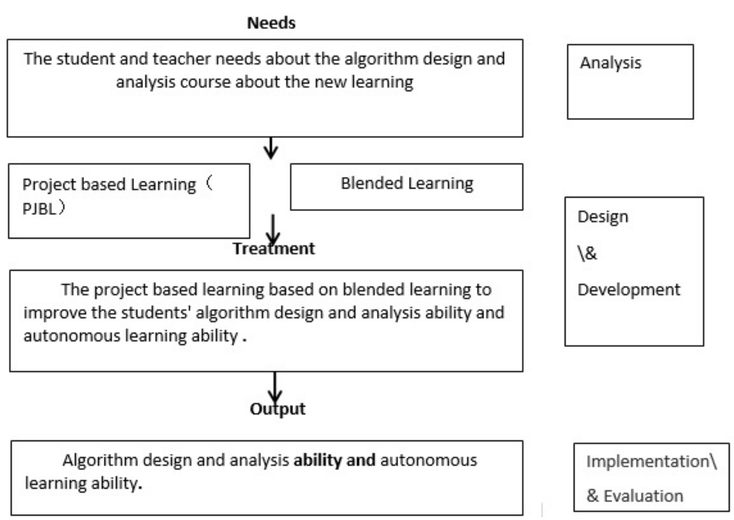

Figure 1: Research framework

RESEARCH METHODOLOGY

Study Design

The study used a mixed-methods approach. In an experimental study, it used the PJBBL model in the domain of algorithm design education. The use of PJBBL in algorithm design is an independent variable, whereas students' academic achievement is the dependent variable. While the needs assessment process utilized a qualitative approach as well.

Participants

The research was conducted at Nanning University's Information Engineering College. Twenty teachers and 100 BS students were randomly selected from the college for interview and questionnaire administration, whereas 66 students were selected through cluster sampling for intervention. The age range of students was 18–22 years, and the age range of teachers was 28–56. At Nanning University's Information Engineering College, the study sought to explore the needs and perspectives of teachers and students regarding Algorithm Design and Analysis capability and students' autonomous learning abilities. Through the use of self-developed instruments, the research aimed to gain valuable insights into the strengths and areas for improvement in the teaching and learning process of Algorithm Design and Analysis.

Process

The entire process was conducted in three research phases, which are:

*Phase 1: Students' and teachers' needs assessment*This phase of the research is dedicated to understanding the requirements of students and teachers concerning Algorithm Design and Analysis capability, as well as exploring students' autonomous learning abilities. The investigation is bifurcated into two key aspects: addressing students' needs and identifying teachers' needs. A mixed-methods approach was employed to gather comprehensive data, utilizing a self-developed questionnaire for students and interviews with teachers.

To assess the needs of students, a self-developed questionnaire was administered to a randomly selected sample of 100 students. The questionnaire elicited insights into students' perceptions and preferences regarding Algorithm Design and Analysis learning. It encompassed questions related to students' familiarity with common algorithms and data structures, confidence in algorithm design, and ability to analyze algorithm efficiency in different contexts. Additionally, the questionnaire inquired about students' experiences with programming implementation and their motivation to enhance their algorithmic skills.

On the other hand, the needs of teachers were evaluated through in-depth interviews conducted with 20 experienced educators by the researchers. A self-developed interview schedule was utilized to delve into the teachers' perspectives on Algorithm Design and Analysis education. The interviews explored various aspects, such as teachers' preferred pedagogical strategies, their challenges in teaching algorithmic concepts, and their suggestions for incorporating effective teaching methods. Moreover, the interviews probed teachers' insights on nurturing students' autonomous learning abilities in the context of Algorithm Design and Analysis.

Before the main data collection, the questionnaire and the interview schedule underwent rigorous validation procedures. Expert opinions were sought to ensure the validity of the content of the instruments, refining them to encompass relevant and meaningful aspects of Algorithm Design and Analysis education. Subsequently, a pretest was conducted with 20 students and 2 teachers to assess the clarity and comprehensibility of the questionnaire and interview schedule, respectively.

The reliability of the questionnaire was assessed using Cronbach's alpha for the five-point Likert scale items, which resulted in an alpha value of 0.801, indicating high internal consistency and reliability of the instrument. The robustness of the questionnaire makes it a valid tool for capturing students' perspectives on Algorithm Design and Analysis capability.

*Phase 2: Design and development*This research phase mainly focuses on developing a new learning model and consists of two parts. One is to design the new model, and the other is to analyze and select the measurement tools used in the experiment. In the first part, project-based learning based on a blended learning model was developed through focus group discussions with the help of five experts. In the second part, the test (used for pre-and post-testing) and scale were constructed with five experts' help for each.

Table 1: The project-based learning based on blended learning model

Step1 Process of the experiment			
1. Subject Teaching:			
Blended Learning			
Teacher activities	Online Q&A	Student activities	Online Write a needs analysis Discussion and questioning
	Off-line Instruct students to determine development projects Instruct students to complete the project needs analysis		Off-line Discuss the content of the demand analysis
2. Application Microsoft Word			
Step2Scenario construction			
1. Subject Teaching			
Teacher activities Blended Learning			
Teacher activities	Online Q&A	Student activities	Online Install various development software and project management software on the computer Discussion and questioning
	Off-Line Organize students to decorate the work environment		Off-Line Arrange the classroom environment
2. Application Microsoft Project, Chaoxing Learning PlatForm,Dev Cpp,Git, Touge Platform			
Step3Divisions of student roles			
1.Subject Teaching			
Teacher activities Blended Learning			
Teacher activities	Online Q&A	Student activities	Online Conduct grouping and division of labor online by oneself Discussion and questioning
	Off-Line Offline guide grouping, explain the precautions for grouping division		Off-Line Report the basis and situation of the division of labor in groups
2.ApplicationChaoxing Learninig Platform			
Step4Produce project plan			
1.Subject Teaching			
Teacher activities Blended Learning			
Teacher activities	Online Q&A	Student activities	Online draw up a plan Discussion and questioning
	Off-Line Describe the development of the project plan		Off-Line Report plan content
2.ApplicationMicrosoft Project,Chaoxing Learninig Platform,			
Step5Project implementation			
1.Subject Teaching			
Blended Learning			
Teacher activities	Online Assign corresponding algorithm knowledge learning requirements and assignments homework correcting Q&A	Student activities	Online Learn the algorithm knowledge required to develop corresponding modules Discuss the difficult content of the algorithm Develop sub-functional modules of the system using learning knowledge Discussion and questioning
	Off Line Parse Job Summarize learning points Answer questions about algorithm knowledge Answer questions during the system development process		Off-Line Report learning algorithm knowledge Ask questions about learning algorithm knowledge Report the development progress of system sub-function modules Propose the challenges of developing system submodules
2.ApplicationChaoxing Learninig PlatForm, Dev Cpp,Git,Touge PlatForm			
Step6Project evaluation and improvement			
1.Subject Teaching			
Blended Learning			
Teacher activities	Online Q&A	Student activities	Submit final project development results Discussion and questioning
	Off-Line Evaluate student development work Propose improvement suggestions Evaluate the overall performance of students in the entire project development		Off-Line Demonstrate software development results Summarize the knowledge and technology of algorithms Propose improvement ideas
2. Application Dev Cpp,Git, Chaoxing Learning Platform			

The experimental process completed in 6 months, lesson plans were used to teach students.

Table 2: Teaching content reconstruction table

chapters	Traditional teaching content	New Learning Model Teaching Content	teaching hours
Chapter 1: Introduction	Course Introduction Basic algorithm concepts Algorithm analysis method	Description and requirements of the new learning mode Needs Analysis of Student Information Management System Data Structure Design of Student Information Management System	4
Chapter 2: Recursive algorithm design technology	Recursive definitions and models Calculation of Recursive Formula Recursive algorithm design Common Recursive Algorithms	Storage Design of Student Data Linear storage of student data Nonlinear storage of college data Optimized storage of class information using recursive algorithms	8
Chapter 3: Exhaustive Method	Concept of Exhaustive Method The Basic Application of Exhaustive Method Recursion and Exhaustive Method	Implementing Student Data Search Function by Exhaustive Method The Implementation of the Function of Sorting Student Data by Exhaustive Method Using Recursive Algorithms to Improve College Data Search and Sorting Functions	8
Chapter 4: Divide and conquer algorithm	Concept of divide and conquer algorithm Solve sorting problems Solve Find Problem Parallel computing	Optimizing the Search Function of Student Data Using the Divide and Conquer Algorithm Optimizing the sorting function of student data using a divide and conquer algorithm	12

*Phase 3: Implement & evaluation*The main purpose of this study is to conduct experiments to study the impact on students' algorithm design and analysis abilities and autonomous learning abilities. It mainly includes three aspects: experimental design, determination of participants, and determination of data analysis methods. Two classes are selected from four according to the cluster sampling method, one as the experimental group and the other as the control group, each with 33 students.

Data collection

The data collection process consists of two stages: the pre-test stage, conducted before the commencement of the experiment, and the post-test stage, administered after the completion of the experiment. The primary focus of the pre-test stage is to gauge students' basic mathematical logic and programming skills. To achieve this, students are given a 100-point paper that assesses their foundational knowledge in these areas. After completing the pre-test, individual scores for each student are recorded.

Moving to the post-test stage, both groups undergo two separate tests. After participating in the learning intervention, the first test assesses students' algorithm design and analysis abilities. This post-test is also conducted on paper, and individual scores are recorded to measure the progress made by each student.

The second test in the post-test stage focuses on evaluating students' autonomous learning abilities. To accomplish this, a scale is utilized to gather information on students' self-directed learning tendencies and ability to take ownership of their learning journey.

The post-test stage is conducted in groups, allowing for a comprehensive comparison of the experimental and control groups. This comparative analysis aids in identifying any significant differences in the outcomes of the two groups, thereby providing valuable insights into the effectiveness of the learning intervention on both algorithm design and analysis ability and students' autonomous learning capability.

The rigorous data collection process, comprising pre-test and post-test stages, enables researchers to measure the impact of the learning intervention on students' algorithmic skills and autonomous learning abilities. The research team can objectively assess and quantify the results by employing test papers and scales.

Data analysis

The students' needs questionnaire is sourced from the Wenquanxing questionnaire platform. Designed using a Likert 5-level scale, the questionnaire gathers valuable insights into students' perspectives on Algorithm Design and Analysis education. The questionnaire results are subject to quantitative analysis, employing means and standard deviations to assess the responses comprehensively.

The teacher interview data is subjected to content analysis for the qualitative aspect. The researchers extract meaningful themes and patterns from the interview responses through this in-depth examination. The content analysis enables a thorough understanding of teachers' perspectives and provides rich qualitative data to complement the quantitative findings.

A Multivariate Analysis of Variance (MANOVA) is employed to analyze the new learning model's overall impact. By comparing the data generated by the experimental and control groups during both the pre-test and post-test stages, the researchers determine the extent to which the new learning model enhances students' algorithm design and analysis abilities and their autonomous learning capability.

Experiment design

The research employed a pre-test, and post-test experimental design, where the experimental group utilized the new learning model for course learning. In contrast, the control group received traditional face-to-face and offline teaching for course learning. Before commencing the teaching experiments, a pre-test was conducted for all students, and the data from the pre-test was recorded.

Following the experiment, both the experimental and control groups underwent a post-test. The post-test comprised paper test papers and a scale to assess the algorithm design and analysis abilities of the two groups of students. Additionally, the scale was used to measure the students' autonomous learning ability. During the post-test, students in both groups were assessed using the paper test papers, providing quantitative data on their algorithm design and analysis performance. Simultaneously, the scale was employed to gather information about the students' autonomous learning ability, offering insights into their self-directed learning tendencies and autonomy in the learning process.

This mixed-methods approach of utilizing both paper test papers and scales allowed for a comprehensive evaluation of students' algorithmic skills and autonomous learning capability. By combining objective quantitative data from the test papers with subjective qualitative data from the scale, the research team gained a well-rounded understanding of the student's learning outcomes and experiences.

The post-test data collection enabled researchers to examine the impact of the new learning model on students' algorithm design and analysis abilities as well as their autonomous learning proficiency. By comparing the post-test results of the experimental and control groups, the study sought to ascertain the effectiveness of the new learning model in enhancing students' algorithmic skills and promoting autonomous learning.

DISCUSSION

Algorithm Design courses are essential for computer science students, as they require knowledge of technology and programming skills. Susanto et al. (2021) emphasize that these courses cover basic programming and logic, fostering logical thinking and problem-solving abilities. Students' logical and abstract thinking skills are honed through programming practice, enhancing problem analysis and creative thinking abilities (Fowler, 2022). Moreover, mastering programming allows students to better understand computer working principles such as memory, CPU, and operating systems, thus improving their practical abilities in computer-related fields. In the modern educational landscape, a blend of online and offline teaching has become a suitable approach for universities and schools (Ashraf et al., 2022).

Some studies support the findings of the Project-Based Blended Learning (PJBBL) model in enhancing students' algorithm design and analysis capabilities. Zhang et al. (2022) conducted a study examining the effects of the PJBBL model in a computer science course focused on algorithm design. The results revealed that students exposed to the PJBBL model demonstrated significantly higher algorithmic proficiency and problem-solving skills than those in a traditional lecture-based setting. Tong et al. (2020) implemented the PJBBL model in an Algorithm Analysis course and assessed students' learning outcomes. The study found that students' algorithmic understanding and analytical abilities significantly improved by integrating real-world projects and blended learning activities. Wang (2023) studied integrating Project-Based Learning (PBL) and Algorithm Design and Analysis in computer science education. The findings highlighted that PBL-based approaches enhanced students' motivation, critical thinking, and teamwork, improving their algorithm design capabilities. Anwar et al. (2022) found that blending face-to-face and online learning approaches can enhance students' algorithmic skills and ability to apply algorithms in practical projects within the electronic engineering domain. Avsec and Jagiełło-Kowalczyk (2021) investigated the impact of the PJBBL model on students' algorithmic design skills and self-directed learning capabilities. The study demonstrated that the PJBBL model enhanced algorithmic proficiency and fostered students' autonomy and motivation in the learning process. These supportive studies provide evidence that aligns with the findings of your PJBBL research, highlighting the model's effectiveness in enhancing students' algorithm design and analysis capabilities. The consistent positive outcomes across multiple studies suggest that the PJBBL model can be a valuable pedagogical approach in Algorithm Design courses, empowering students to excel in algorithmic thinking and problem-solving skills.

On the contrary, Basar et al. (2021) researched the effectiveness of traditional face-to-face teaching in Algorithm Design courses. They found that students taught through conventional methods exhibited comparable algorithmic skills and analysis capability to those taught using the PJBBL model. Paul and Jefferson (2019) conducted a study comparing students' academic performance in a PJBBL-based Algorithm Design course to those in a fully online learning environment. Surprisingly, they found no significant difference in the two groups algorithmic skills and analysis abilities, challenging the superiority of the PJBBL model. In previous research, students' algorithm design and analysis proficiency were assessed before and after exposure to the PJBBL model. Unexpectedly, the results showed no significant improvement in the algorithmic skills of the experimental group compared to a control group taught through traditional lecture-based methods. Qi and Meng (2021) conducted a study comparing the effectiveness of various teaching methods, including PJBBL, in different programming courses. Surprisingly, they found that while the PJBBL model showed positive results in some courses, it did not consistently enhance algorithmic skills in all programming contexts. These contradictory studies challenge that the PJBBL model universally enhances students' algorithm design and analysis capabilities. While the PJBBL model has demonstrated positive outcomes in some studies, the findings from these contradictory studies raise questions about the model's consistent effectiveness across all educational settings and subjects. It highlights the need for further research and investigation to better understand the complex dynamics of educational interventions and their impact on student learning outcomes.

Theoretical and practical implications

The findings of our PJBBL study contribute to the growing body of research supporting the effectiveness of project-based blended learning in the context of Algorithm Design education. This adds to the existing literature on innovative pedagogical approaches that promote active learning, engagement, and critical thinking among students. The successful implementation of the PJBBL model aligns with constructivist learning principles, emphasizing that learners construct knowledge through meaningful interactions with the subject matter and real-world experiences. The study reinforces that hands-on, project-based learning enhances students' understanding and retention of complex algorithmic concepts. Our research highlights the significance of promoting students' autonomous learning abilities within the PJBBL framework. By incorporating online and offline learning experiences, the model encourages students to take ownership of their learning journey, fostering lifelong learning skills essential for their future careers.

The study's practical implications can guide curriculum designers and educators in incorporating project-based blended learning strategies into Algorithm Design courses. Educators can create dynamic learning experiences that enhance students' algorithmic skills and critical thinking by integrating real-world projects and leveraging digital resources. The successful implementation of the PJBBL model necessitates equipping teachers with the necessary training and support. Professional development opportunities focused on project design, blended learning techniques, and student-centered instruction can empower educators to effectively implement the model in their classrooms. The study's outcomes can inform institutional policy decisions regarding adopting and promoting innovative teaching methodologies. Recognizing the benefits of project-based blended learning, educational institutions can encourage and incentivize faculty to explore and implement such approaches across various disciplines.

Limitations and future research directions

The study's sample size, though sufficient for the specific research setting, may limit the generalizability of the findings to a broader population. Future research should consider larger and more diverse samples to increase the external validity of the results. The post-test phase only assessed students' immediate learning outcomes after exposure to the PJBBL model. Longer-term follow-up assessments could provide insights into the model's sustained impact on students' algorithmic skills and autonomous learning abilities over time. The study was conducted at a specific educational institution, and contextual factors such as teaching practices and resource availability may have influenced the results. Future research should explore the PJBBL model's effectiveness across different educational settings and student populations.

Future research could conduct comparative studies to directly compare the effectiveness of the PJBBL model with other pedagogical approaches, such as traditional face-to-face instruction or fully online learning. This would provide a more comprehensive understanding of the model's relative advantages and limitations. Longitudinal research designs could investigate the long-term effects of the PJBBL model on students' algorithmic competencies and self-directed learning abilities. Tracking students' progress over an extended period would provide valuable insights into the sustainability of the model's impact. Exploring the impact of the PJBBL model on student engagement, motivation, and attitudes toward algorithm design could provide additional dimensions of its effectiveness. Understanding the factors influencing student motivation in this context would inform strategies to optimize the learning experience.

CONCLUSION

The results of the study indicate that the PJBBL model has shown promising outcomes in enhancing students' algorithm design and analysis capabilities. Integrating real-world projects and blended learning methods has deeply engaged students, fostering a better understanding of algorithmic concepts and their practical application. This pedagogical approach has empowered students to master common algorithms and data structures, design efficient algorithm implementations, optimize algorithms for enhanced performance, and analyze algorithm efficiency under various conditions.

Furthermore, the research findings highlight the positive influence of the PJBBL model on students' autonomous learning abilities. By incorporating online and offline learning experiences and encouraging self-directed learning, students have demonstrated higher motivation and engagement in their algorithmic learning journey. The PJBBL model has nurtured students' awareness of lifelong learning and adaptability to future career challenges, instilling the essential skills needed for sustained success in the dynamic IT industry. The insights obtained from teachers' perspectives have also been valuable in refining the implementation of the PJBBL model. Teachers' feedback has shed light on effective pedagogical strategies, enabling them to create a conducive learning environment and support students in their algorithmic learning endeavors. The research demonstrates the efficacy of the Project-Based Blended Learning (PJBBL) model in Algorithm Design and Analysis education. The integrated approach has proven to be a transformative pedagogical method, equipping students with essential algorithmic skills and nurturing their autonomous learning capabilities.

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