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IMPROVING STUDENTS' PROGRAMMING SKILLS THROUGH PROJECT-BASED LEARNING IN SECONDARY TECHNICAL SCHOOLS

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Abstract

Programming education remains one of the most challenging components of computer science instruction in secondary technical schools. Traditional lecture-based approaches often fail to develop strong practical skills and sustained motivation. This study examines the effectiveness of project-based learning (PBL) in improving programming competence among students at Jizzakh City Technical School No. 1. A quasi-experimental design was conducted over one semester with 84 students divided into control and experimental groups. The experimental group was instructed using project-based learning, while the control group followed conventional teaching methods. Pre- and post-tests, structured observation, and student surveys were used for data collection. The results indicate statistically significant improvements in programming achievement, problem-solving skills, and learning motivation in the experimental group. The findings confirm that project-based learning is an effective strategy for enhancing programming education in vocational institutions.

Keywords

project-based learning, programming education, vocational training, computer science instruction, active learning

1. Introduction

Programming competence is increasingly recognized as a core skill in modern technical education. Secondary technical schools are responsible for preparing students for employment in information technology and related fields. However, many students experience difficulties in understanding programming concepts, particularly algorithmic thinking and debugging processes (1). Traditional lecture-based instruction often limits opportunities for active engagement and practical application (2).

Research in educational methodology demonstrates that active learning approaches significantly improve student performance in STEM disciplines (3). Project-based learning (PBL), which engages students in solving practical problems and producing functional outputs, has gained attention as an effective instructional model (4). Grounded in constructivist theory (5,6), PBL promotes inquiry, collaboration, and deeper understanding of subject matter.

The present study investigates whether project-based learning can significantly improve programming skills among students in a secondary technical school setting.

2. Literature Review

Programming education research consistently identifies cognitive overload and abstract reasoning as major barriers for beginners (1). Students frequently memorize syntax without fully

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understanding program logic, which results in fragile knowledge structures. Passive teaching approaches further reduce conceptual clarity and limit meaningful engagement (2).

Project-based learning shifts instruction from teacher-centered explanation to student-centered exploration. According to Thomas (4), PBL organizes learning around complex tasks resulting in realistic products. Krajcik and Blumenfeld (7) emphasize that project-based environments foster inquiry and collaborative knowledge construction. Empirical research shows that active learning significantly increases academic achievement compared to traditional lectures (8). In vocational contexts, project-based approaches enhance knowledge transfer and applied competence (9). Additionally, motivation theory suggests that autonomy and collaboration strengthen persistence and improve learning outcomes (10).

Despite strong international evidence supporting PBL, its systematic application in secondary technical schools remains limited. This study contributes empirical data addressing this gap.

3. Methodology

The study employed a quasi-experimental design over a 16-week semester. Participants included 84 second-year students specializing in information technology at Jizzakh City Technical School No. 1. Students were divided into an experimental group (42 students), which received project-based instruction, and a control group (42 students), which followed traditional lecture-based instruction. Both groups studied identical programming content, including variables, control structures, functions, arrays, and introductory database integration.

The experimental group completed two structured team-based projects: a student information management system and an inventory tracking application. The control group completed conventional programming exercises covering the same theoretical material. Assessment tools included pre-tests and post-tests (100-point scale), structured classroom observation protocols, a motivation survey based on a five-point Likert scale, and a standardized project evaluation rubric.

4. Results

The analysis began by comparing pre-test scores to ensure baseline equivalence between groups. The control group achieved a mean score of 56.8, while the experimental group scored 57.3, indicating no statistically significant difference in prior knowledge. This confirmed that both groups started from comparable levels of programming competence.

At the end of the semester, both groups demonstrated improvement; however, the magnitude of progress differed substantially. The control group's mean post-test score increased to 61.9, representing an average improvement of 5.1 points (approximately 9%). In contrast, the experimental group achieved a mean post-test score of 70.5, reflecting an average increase of 13.2 points (approximately 23%). Statistical comparison confirmed that the improvement observed in the experimental group was significant at the 0.05 level, demonstrating a clear instructional impact.

Further qualitative and quantitative analysis revealed that students exposed to project-based learning showed stronger development in algorithmic thinking and logical structuring of programs. Their solutions contained fewer structural errors, particularly in loop construction and conditional statements. Debugging performance also improved markedly: students in the experimental group resolved runtime errors independently in a majority of observed cases, whereas students in the control group more frequently relied on teacher assistance. Moreover,

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project-based learners demonstrated better code organization, including clearer modularization and more consistent commenting practices, suggesting deeper comprehension of programming architecture rather than surface-level syntax memorization.

Application-based assessment tasks further highlighted performance differences. When presented with a novel programming problem not directly practiced during lessons, 71% of students in the experimental group produced functional and logically consistent solutions, compared to 46% of students in the control group. This indicates stronger knowledge transfer and adaptive problem-solving ability among project-based learners.

Student motivation data supported these findings. Survey results showed that 85% of students in the experimental group reported increased interest in programming, while only 52% of students in the control group expressed similar growth in interest. Additionally, a large majority of project-based learners reported greater confidence in their ability to independently design software solutions. Classroom observations corroborated these self-reported perceptions, as students in the experimental group participated more actively in discussions, collaborated more frequently during coding sessions, and displayed higher persistence when encountering programming challenges.

Evaluation of final project outputs provided additional evidence of enhanced competence. The experimental group achieved an average project rubric score of 82.4 out of 100, reflecting functional correctness, structural clarity, user-interface coherence, and effective teamwork integration. In contrast, equivalent individual task performance in the control group averaged 64.7 points. These results collectively demonstrate that project-based learning not only improves theoretical understanding but also strengthens applied programming skills and learner engagement.

5. Discussion

The findings demonstrate that project-based learning substantially enhances programming competence compared to traditional lecture-based instruction. Students engaged in authentic software development tasks were required to integrate theoretical knowledge with practical implementation, which strengthened conceptual understanding and algorithmic reasoning.

Improved motivation and autonomy appear to have contributed significantly to learning gains. Students reported greater ownership of their projects, which encouraged persistence and deeper engagement. Collaborative project work also supported communication and teamwork skills essential for professional practice in the IT field.

While initial challenges included time management and uneven participation among team members, structured teacher guidance minimized these issues. Overall, the results align with established research supporting active learning methodologies in technical education.

6. Conclusion

This study confirms that project-based learning significantly improves programming achievement, practical competence, and student motivation in secondary technical schools. Compared to traditional lecture-based instruction, PBL produces stronger learning gains and higher engagement levels.

The integration of structured project-based methodologies into programming curricula can enhance educational quality and better prepare students for professional IT careers. Future

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research may expand the sample size, investigate long-term retention effects, and explore integration with digital collaboration technologies.

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