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FACULTY OF INFORMATION AND COMMUNICATION TECHNOLOGIES - BITOLA
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Kostandina Veljanovska, PhD

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Introduction

The International conference on Applied Internet and Information Technologies is a traditional meeting held every year, that sprouts out of collaboration between the University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia and the University "St. Kliment Ohridski", Faculty of Information and Communication Technologies - Bitola, Republic of North Macedonia. The XIII AIIT2023 was held in Bitola, Macedonia on which besides the participants from Serbia and Macedonia there were researchers from Croatia, Bosnia and Herzegovina, Hungary, Finland, Russia, Turkey, Egypt, India and Australia whose contribution was either as authors or as reviewers of the papers.

At the Conference were presented innovative findings in the field of information systems, communications and computer networks, software engineering and applications, data science and big data technologies, artificial intelligence, intelligent systems, business intelligence and IT support to decision-making, data and system security, distributed systems, Internet of Things and smart systems, embedded systems, computer graphics, IT management, e-commerce, e-government, e-education, Internet marketing, and IT practice and experience.

The Conference chairs would like to express gratitude to the authors for their contributions and to express special gratitude to the reviewers for their tremendous work done for selecting the papers with their valuable comments and suggestions that contributed to improve the quality of the papers. Out of more than 60 submitted papers, 51 were selected, presented at the Conference and are published in this proceedings.

The work during the conference was organized in nine sessions: plenary session, five in-person oral sessions, one video session and two poster sessions. During the conference, a round table with participants from academic organizations and IT industry was successfully organized. The theme of the discussions at the round table was "Strengthening the capacities of Faculty of ICT for the realization of strategic cooperation with companies from the IT industry".

AIIT 2023 was very successful conference with fruitful exchange of experiences among the participants reviving the hope of further strengthening a friendly environment after the pandemic crisis. We hope that we will continue with the contribution to the further deepening the development of Internet and information technologies research.

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Kostandina Veljanovska, Ph.D. finished BSc in Computer Science at the University "Sts. Kiril i Metodi", Skopje. Her first MASc in Applied Engineering she received at the University of Toronto, Toronto, Canada. Her second MSc and also her PhD in Technical Sciences she received at the University “St. Kliment Ohridski” - Bitola, R. Macedonia. Her postdoctoral studies in Artificial Intelligence she attended at the Laboratory of Informatics, Robotics and Microelectronics at the University of Montpellier, Montpellier, France. She worked as a Research assistant at the Faculty of Applied Science, University of Toronto, Canada. She also, worked as a researcher in research team for Constraints, Learning and Agents at LIRMM, University of Montpellier. Since 2008, she works as a Full Professor in Information Systems and Networks, Artificial Intelligence and Systems and Data Processing at the Faculty of Information and Communication Technologies, University “St. Kliment Ohridski” - Bitola, Rebublic of North Macedonia. Her research work is focused on artificial intelligence, machine learning techniques and intelligent systems. She has published numerous scientific papers in the area of interest, as well as several monographic items. She is a reviewing referee for well-known publishing house, journals with significant impact factor in science and also, member of editorial board of several international conferences.

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Eleonora Brtka, Ph.D. is an associate professor at the Information Technology department at the University of Novi Sad, Technical Faculty „Mihajlo Pupin“, Zrenjanin. She has received her PhD in Information technology in 2015. Current research interests include: data science techniques and methods, programming languages, education, artificial intelligence and intelligent agent technologies. She is the author or co-author of several articles published in international journals and in the proceedings of international conferences. She participated in several national funded projects.

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C O N T E N T

Exploring the Impact of Pair Programming on Student Achievement: A Comparative Analysis

Ilker Ali[1], Aybeyan Selim[1], Blagoj Ristevski[2] and Sonja Mančevska[2]

[1]*Faculty of Engineering and Architecture, International Vision University, Gostivar, North Macedonia*

[2]*Faculty of Information and Communication Technologies – Bitola, University "St. Kliment Ohridski" – Bitola, Republic of Macedonia*

ilker@vision.edu.mk, ilker.ali@uklo.edu.mk; aybeyan@vision.edu.mk; blagoj.ristevski@uklo.edu.mk; sonja.manchevska@uklo.edu.mk

Abstract:
This study investigates the impact of the pair programming technique on student success in a primary school setting. The research was conducted at Mustafa Kemal Ataturk Primary School in Gostivar, Macedonia, using data from the e-Dnevnik[1] database. This study involved two groups: Group 1, where pair programming was applied, and Group 2, acting as a control without this intervention. Both groups underwent pre- and post-intervention tests to evaluate their programming proficiency. The results revealed that the initial programming proficiency levels were comparable across the groups. The acceptance of the null hypothesis in the pre-intervention phase indicated the similarity of the groups before the pair programming technique was introduced. In the post-intervention analysis, while the null hypothesis showed comparable results, a deeper exploration revealed a significant difference in success rates between the two groups post-implementation. These findings suggest that the pair programming technique positively influences student success. The study contributes insights into innovative teaching methods and their potential impact on student outcomes.

Keywords:
pair programming, educational technology, statistical data analysis, innovative teaching methods

1. Introduction

In the modern landscape of education, the pursuit of effective teaching methodologies is a paramount endeavor [1]. As classrooms evolve to accommodate digital advancements, innovative techniques gain prominence for their potential to enhance student engagement and achievement. One such technique that has gained attention is pair programming, a collaborative approach wherein two students jointly work on coding tasks [2]. Through shared problem-solving and real-time collaboration, pair programming is believed to deepen understanding and foster critical thinking [3] [4].

This study explores the impact of pair programming on student achievement within the primary school context. By assessing its influence on programming proficiency, problem-solving skills, and learning outcomes, we aim to provide insights into the efficacy of this pedagogical strategy [5]. The comparative analysis involves two distinct groups: one engaged in pair programming and the other following traditional individual programming methods.

[1] Web-based electronic register software for primary and secondary school education organizations in North Macedonia

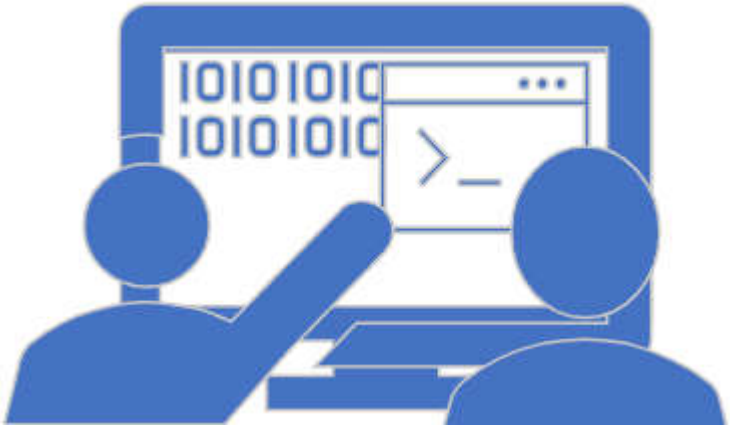

Figure 1 - Pair programming - Students act as drivers and navigators.

The research extends from the premise that innovative teaching methods have the potential to revolutionize classroom dynamics, thereby shaping the success trajectories of students [6]. Pair programming aligns with this philosophy by capitalizing on collaborative learning and the interplay of diverse perspectives to enhance programming proficiency [7].

This paper sets out to explore the effects of pair programming on student achievement by analyzing the results of our comparative study. We delve into the implications of our findings for education, shedding light on the potential benefits of this approach and contributing to the ongoing dialogue on effective teaching methodologies.

2. Application of Pair Programming in Primary Education

Pair programming, a collaborative technique commonly utilized in software development, has been increasingly recognized for its potential to enrich primary education environments [8]. This innovative approach involves two students working together on a single computer, one assuming the role of the "driver," responsible for writing code, and the other as the "observer," offering insights, suggestions, and reviewing the code in real-time, as shown on Fig. 1. While pair programming has been extensively applied in professional contexts, its adoption in primary education presents a promising avenue to enhance learning outcomes, foster teamwork, and cultivate foundational coding skills.

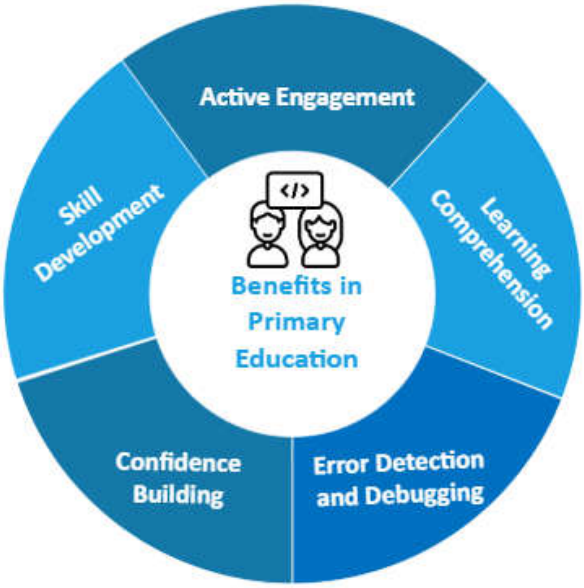

Figure 2 - Benefits in Primary Education.

The main benefits in primary education are shown on Fig. 2:

1. **Active Engagement**: Pair programming captures students' attention through interactive and hands-on activities. The collaborative nature of the approach encourages participation, as students work together to solve problems, share ideas, and develop solutions [9].
2. **Skill Development**: Pair programming promotes the development not only of the coding skills but also crucial soft skills such as communication, teamwork, and problem-solving. Students learn to articulate their thought processes, discuss ideas, and provide constructive feedback to their partners.
3. **Learning Comprehension**: Through real-time discussions, students gain a deeper understanding of programming concepts. The process of explaining code to a partner fosters a more thorough grasp of the material, reinforcing learning outcomes [10].
4. **Confidence Building**: Collaborative problem-solving can boost students' self-assurance. As they work alongside a partner, students can rely on one another's strengths, which in turn cultivates a sense of accomplishment and resilience [11].
5. **Error Detection and Debugging**: The collaborative nature of pair programming enables immediate error detection. Partners can identify mistakes or misunderstandings early, leading to quicker resolution and a more efficient learning process.

During the implementation of the pair programming, the following should be considered:

1. **Pair Formation**: Pairs can be formed based on varying skill levels, promoting peer learning. Mixing students with different proficiencies encourages a supportive environment where both participants contribute to the partnership [12].
2. **Rotation**: Periodically rotating roles between the driver and observer ensures that students experience both aspects of coding and teamwork. This practice enhances empathy and a well-rounded understanding of the process [13].
3. **Clear Guidelines**: Establish clear guidelines on communication, respect, and collaborative problem-solving. Encourage students to explain their thought processes and exchange ideas freely.
4. **Adaptable Challenges**: Tailor coding challenges to suit the pair programming approach. Assign tasks that require joint problem-solving and allow for creativity in solution development [14].
5. **Feedback and Reflection**: Incorporate feedback sessions where pairs discuss their experiences, challenges they've faced, and lessons they've learned. This reflective practice enhances the learning process and encourages continuous improvement.

Incorporating pair programming into primary education aligns with modern pedagogical trends that emphasize active learning, collaboration, and technology integration. By fostering a collaborative spirit and nurturing coding proficiency from an early age, educators set the stage for students to embrace technology with confidence and enthusiasm in an increasingly digital world [15].

3. Research methodology

The data was sourced from the e-Dnevnik database of Mustafa Kemal Ataturk Primary School in Gostivar. To evaluate the influence of the pair programming technique on success, both the independent programming and pair programming groups underwent the same test. The test results data was analyzed using appropriate methods, and the outcomes for both groups were examined.

3.1. Material

The study incorporated two distinct tests, which were administered to all participant groups. These tests covered diverse task categories. In the first category, participants were required to convert decimal numbers to binary and answer theoretical questions about variables in the C++ programming language. In the second category, students were tasked with constructing and coding solutions on a computer. Within this problem set, three question types were presented:

1. Multiple-choice questions.
2. Questions requiring written answers.
3. Questions involving coding in the C++ programming language.

3.2. Procedure for data collection

The process of data collection involved two distinct phases: the pre-pair programming technique assessment, and the assessment of challenges encountered during pair programming. The execution of each stage extended over a twelve-week period in this research. The pre-pair programming technique test aimed to proactively identify potential issues that might emerge during the subsequent pair programming tests [16]. The assessment encompassed a total of 85 participants.

4. Results

Commencing the data analysis endeavor, the primary stride encompassed the calculation of the grade averages and corresponding standard deviations for each class within the sixth grade, preluding the application of the pair programming technique. The encapsulated outcomes are showcased in Table 1, where a harmonious alignment of mean values and standard deviations is evident in the context of the pre-pair programming stage. This visual representation substantiates the notion that the levels of programming acumen exhibited minimal discrepancies among the various classes.

Table 1:
Group statistics of classes before the pair programming technique

	N	Average Grade	Standard Deviation of Grades
VI-1	14	3.60	2.61
VI-2	22	2.83	2.40
VI-3	15	3.33	2.54
VI-4	23	2.99	2.46
VI-5	11	3.13	2.50
Total	85		

To assess the influence of pair programming on student success within a simplified context, two distinct groups were established: Group 1 and Group 2. In Group 1, the pair programming technique was applied, while in Group 2, this technique was not incorporated.

Following this stage, our focus shifted to selecting the subsequent procedure for analyzing the outcomes of both the pair programming (Group 1) and individual programming (Group 2) groups. In determining the suitable approach, we evaluated the distribution of the results, which exhibited normal distribution characteristics. Consequently, we opted for the Independent-Samples t-test as the analytical technique, considering its compatibility with data conforming to a normal distribution.

To ascertain the comparability of the groups, we administered the Levene test for equality of variances in the gathered data [17]. In this context, we formulated the subsequent null and alternative hypotheses[2] for the test's results:

$$H_0: \sigma^2_{Group\ 1} = \sigma^2_{Group\ 2}$$
$$H_a: \sigma^2_{Group\ 1} \neq \sigma^2_{Group\ 2}$$

Table 2:
Levene's test for equality of variances before pair programming technique

	F	Sig.
Equal variances assumed	.150	.699
Equal variances not assumed		

[2] σ^2 represent the variance of the groups.
H_0 : The variances of two groups are equal, indicating that there is no variation in the response variable among different treatment groups.
H_a: The variances of the groups are not equal, suggesting that there is variation in the response variable among different treatment groups.

Analyzing the findings presented in Table 2, it becomes evident that the calculated significance level stands at 0.699, which is greater than the conventional threshold of 0.05. Consequently, the null hypothesis (H_0) is accepted. This implies that the differences in outcomes before the implementation of the pair programming technique between Group 1 and Group 2 were comparable. In simpler terms, the initial results of both groups exhibited similarity prior to the utilization of the pair programming technique.

We utilized the t-test for equality of means as a means to compare the average success levels between the two groups, and the resulting hypotheses[3] are as follows.

$$H_0: \bar{X}_{Group\ 1} = \bar{X}_{Group\ 2}$$
$$H_a: \bar{X}_{Group\ 1} \neq \bar{X}_{Group\ 2}$$

Extracting insights from the data provided in Table 3, we see that the computed significance value stands at 0.834, surpassing the conventional threshold of 0.05. Consequently, the null hypothesis (H_0) finds acceptance in this scenario. This pivotal outcome underscores that a notable discrepancy in success rates between the two groups is absent. In simpler terms, the pre-existing state of the groups was closely akin before the initiation of the pair programming technique.

The affirmative acceptance of the null hypothesis implies that any observed disparities in success rates post-implementation can be attributed to the introduced technique's influence rather than inherent discrepancies. The alignment of the groups' success metrics is a critical foundation for further examining and assessing the technique's efficacy. As the experiment unfolds, these insights lay the groundwork for a comprehensive evaluation of the technique's impact on the success rates of the involved groups.

Table 3:
t-test for equality of means before the pair programming technique

T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
.210	83	.834	.116	.553

This analysis underscores the notion that the two groups were nearly indistinguishable regarding their baseline characteristics before integrating the pair programming approach. It is worth noting that the engagement and alignment of the two groups' performance metrics provide a solid foundation for meaningful comparisons post-intervention. Group 1 underwent a three-month training phase involving the pair programming technique.

After training, we apply the same test with the same hypotheses to check the impact of pair programming on students' success. The testing results are given in Table 4 and Table 5.

Table 4:
Levene's test for equality of variances after pair programming technique

	F	Sig.
Equal variances assumed	3.856	.053
Equal variances not assumed		

The findings presented in Table 4 indicate that the significance value observed in the posttest was 0.053, which surpasses the threshold of 0.05. As a result, we accept the null hypothesis (H_0). This outcome suggests that the two groups can be comparable in their post-testing results, as the variances in their respective test outcomes exhibited parity. Consequently, we deduce that the efficacy of implementing the pair programming technique applies to assessing the results of these two groups.

[3] $\bar{X}$ represent the mean of the groups.
H_0 : There is no significant difference among the means of the groups. In other words, both groups means are equal.
H_1: There is a significant difference among the means of the groups. At least one group mean is different from the others. There is a significant difference among the means of the groups. At least one group mean is different from the others.

Table 5:
t-test for equality of means after the pair programming technique

T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
3.959	83	.000	2.015	.509
4.015	79.082	.000	2.015	.502

According to the results in Table 5, the meaning value is 0.00 <0.05, so in this case, Ha is accepted. This means there is a significant difference in the success of Group 1 and Group 2 after the application of pair programming. Consequently, we conclude that sufficient evidence suggests that the pair programming technique is an effective teaching method and increases the student's success. The means of success after pair programming is given in Table 6.

Table 6:
Group statistics after pair programming technique

	N	Mean	Std. Deviation	Std. Error Mean
Pair Programming	36	3.75	2.196	.366
Individual Programming	49	2.63	2.405	.344

5. Discussion

While this study contributes valuable insights into the impact of the pair programming technique on student success, it is important to acknowledge certain limitations that may have influenced the results and interpretations.

- **Sample Size and Generalizability:** The study was conducted with a relatively small sample size of 85 participants. This limited sample size might restrict the generalizability of the findings to a broader student population. A larger and more diverse sample could provide a more comprehensive understanding of the technique's effectiveness across different demographic and educational contexts.
- **Duration of Intervention:** The study implemented the pair programming technique within a three-month period. This duration might not fully capture the long-term effects of the technique on student success. Longer-term studies could reveal how the impact of pair programming evolves over extended periods of time.
- **Contextual Factors:** The study was conducted within the specific context of Mustafa Kemal Ataturk Primary School in Gostivar. Different schools or institutions with varying resources, teaching methods, and student populations might yield different outcomes. Cultural, socio-economic, and institutional factors could influence the effectiveness of the pair programming technique.
- **Test Selection and Measurement:** The study utilized specific tests to measure student success. The choice of tests and the specific skills they measure could limit the scope of the findings. A more comprehensive range of assessments could provide a more holistic understanding of the technique's impact on diverse aspects of student success.
- **External Variables:** The study might not have accounted for all potential external variables that could influence student success. Factors such as individual learning styles, prior programming experience, and the level of student engagement with the technique could impact the observed outcomes.
- **Experimental Design:** The study employed a quasi-experimental design with Group 1 receiving the pair programming intervention and Group 2 acting as the control. While efforts were made to ensure comparability between the groups, inherent differences between the groups could still influence the results.
- **Learning Curve and Adaptation:** Students in Group 1 might have experienced a learning curve when adapting to the pair programming technique. The initial phases of implementation might

not accurately reflect the technique's long-term effects, potentially influencing the observed success rates.

- **Participant Motivation:** The study did not extensively explore participant motivation, interest, or attitude toward pair programming. These psychological factors can play a significant role in the effectiveness of any educational technique.
- **Teacher Influence:** The role of teachers in facilitating pair programming and creating a conducive learning environment could impact the outcomes. Variations in teacher expertise and teaching styles might introduce confounding variables.
- **Time Constraints:** The study's three-month timeline might have imposed time constraints on the effectiveness of the pair programming technique. A more flexible and extended implementation period might yield different results.

6. Conclusion

This study delved into the impact of the pair programming technique on student success within the context of Mustafa Kemal Ataturk Primary School in Gostivar. Through a comparative analysis of Group 1 (pair programming applied) and Group 2 (individual programming), valuable insights were gained into the efficacy of this innovative teaching method.

The study's findings unveiled several significant insights. First, the preliminary analysis revealed that the two groups displayed comparable baseline characteristics regarding programming understanding, as indicated by the harmonious alignment of mean values and standard deviations. This served as a solid foundation for meaningful comparisons throughout the study.

The application of the pair programming technique demonstrated its potential to enhance student success. Accepting the null hypothesis in the pre-intervention phase highlighted the comparability of the two groups, setting the stage for assessing the technique's impact. Moreover, the null hypothesis's acceptance in the post-intervention step implied a lack of significant success rate disparities between the groups post-implementation.

However, a closer examination of the same post-intervention phase results revealed a significant difference in success rates between Group 1 and Group 2, confirming the positive influence of the pair programming technique. This outcome underscored the technique's effectiveness as a teaching approach, suggesting collaborative programming enhances student success.

Despite the valuable contributions, this study is not without limitations. The relatively small sample size, contextual factors, and specific measurement tools employed all pose potential constraints on the generalizability and scope of the findings.

This study contributes to the ongoing exploration of innovative teaching methodologies and their impact on student success. The evidence gathered supports the notion that the pair programming technique has the potential to improve student success rates significantly. As education evolves, further research is warranted to explore the technique's effectiveness across diverse settings, demographics, and learning outcomes. The findings of this study, while shedding light on the positive effects of pair programming, invite continued investigation into optimizing its implementation and understanding the nuances of its impact on student success.

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