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ORIGINAL

Assessing the Impact of a STEM Learning Project Model on Artificial Intelligence Education in Higher Learning Institutions

Evaluación del impacto de un modelo de proyecto de aprendizaje STEM en la enseñanza de la inteligencia artificial en instituciones de enseñanza superior

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ABSTRACT

This study investigates the effectiveness of the STEM Learning Project model in enhancing student outcomes in Artificial Intelligence (AI) courses at higher education institutions. The research aimed to assess the model's impact on students' cognitive, affective, and psychomotor skills, with a focus on fostering active participation, problem-solving, and interdisciplinary knowledge integration. Employing a mixed-methods approach, the study utilized both qualitative and quantitative data collection methods. The experimental group engaged in the STEM Learning Project, while the control group followed a traditional AI curriculum. Changes in student knowledge and engagement were measured using pre- and post-test surveys, complemented by qualitative insights obtained from interviews and focus group discussions. The results demonstrated progress in both groups, though the experimental group achieved a greater increase in post-test scores (29,87) compared to the control group (29,21). Statistical analyses confirmed that the data satisfied normality and homogeneity assumptions, allowing for parametric testing. An independent sample t-test revealed a significant difference in post-test scores between the two groups, highlighting the effectiveness of the STEM Learning Project model in enhancing students' AI-related skills. This approach notably improved students' cognitive abilities and interdisciplinary knowledge in AI education, establishing it as a promising strategy for preparing students to address the demands of the AI industry. Future research could explore the model's long-term impact on career readiness and its applicability to other technology-driven educational settings.

Keywords: STEM Learning Project; Artificial Intelligence; Effectiveness.

RESUMEN

Este estudio investiga la eficacia del modelo del Proyecto de Aprendizaje STEM para mejorar los resultados de los estudiantes en cursos de Inteligencia Artificial (IA) en instituciones de educación superior. El objetivo de la investigación era evaluar el impacto del modelo en las habilidades cognitivas, afectivas y psicomotoras de los estudiantes, centrándose en el fomento de la participación activa, la resolución de problemas y la integración de conocimientos interdisciplinarios. Empleando un enfoque de métodos mixtos, el estudio utilizó métodos de recopilación de datos cualitativos y cuantitativos. El grupo experimental participó en el Proyecto de Aprendizaje STEM, mientras que el grupo de control siguió un plan de estudios de IA tradicional. Los cambios en los conocimientos y el compromiso de los estudiantes se midieron mediante encuestas antes y después de las pruebas, complementadas con datos cualitativos obtenidos en entrevistas y grupos de discusión. Los resultados demostraron progresos en ambos grupos, aunque el grupo experimental logró

un mayor aumento en las puntuaciones posteriores a la prueba (29,87) en comparación con el grupo de control (29,21). Los análisis estadísticos confirmaron que los datos cumplían los supuestos de normalidad y homogeneidad, lo que permitía realizar pruebas paramétricas. Una prueba t de muestras independientes reveló una diferencia significativa en las puntuaciones posteriores a la prueba entre los dos grupos, lo que pone de relieve la eficacia del modelo del Proyecto de Aprendizaje STEM para mejorar las habilidades de los estudiantes relacionados con la IA. Este enfoque mejoró notablemente las capacidades cognitivas y los conocimientos interdisciplinarios de los estudiantes en la enseñanza de la IA, estableciéndolo como una estrategia prometedora para preparar a los estudiantes para hacer frente a las demandas de la industria de la IA. Futuras investigaciones podrían explorar el impacto a largo plazo del modelo en la preparación profesional y su aplicabilidad a otros entornos educativos impulsados por la tecnología.

Palabras clave: Proyecto de Aprendizaje STEM; Inteligencia Artificial; Eficacia.

INTRODUCTION

The global need for skilled professionals in Science, Technology, Engineering, and Mathematics (STEM) has grown substantially in recent years. These disciplines are instrumental in fostering innovation and addressing intricate challenges, particularly in domains like artificial intelligence (AI), data science, and machine learning. As technology continues to advance at a rapid pace, conventional educational methods are frequently viewed as inadequate for preparing students to thrive in these dynamic and rapidly evolving industries. In higher education, there is an urgent need to revamp curricula to not only deliver theoretical knowledge but also cultivate practical problem-solving skills and interdisciplinary thinking.[1,2]

An increasingly recognized method in recent years is the incorporation of STEM-focused learning projects. These initiatives prioritize hands-on, project-based learning (PBL), effectively connecting theoretical knowledge with practical application. PBL is highly regarded for its capacity to actively involve students in the learning experience, fostering teamwork, analytical thinking, and the ability to address real-world challenges.[3] Despite its potential, there is limited research on how STEM learning projects can be effectively incorporated into specialized courses such as Artificial Intelligence (AI), which require a combination of theoretical knowledge and technical skills.[4]

The Challenges in AI Education

Artificial Intelligence is a highly interdisciplinary field that draws from computer science, mathematics, and engineering. Teaching AI requires not only an understanding of algorithms and programming languages but also the ability to apply these skills to real-world challenges. Traditional AI courses in higher education have often focused heavily on lectures and theoretical concepts, which may fail to engage students or provide them with the skills needed for practical application.[1,2] This lack of engagement can result in students feeling disconnected from the material, leading to lower retention rates and a diminished interest in pursuing careers in AI and related fields.[3]

Additionally, many AI courses lack an integrated approach that combines elements of STEM disciplines. This siloed structure makes it difficult for students to connect knowledge from various fields, which is essential for solving complex AI problems.[4] For instance, understanding the mathematical foundations of algorithms is crucial, yet many courses do not sufficiently emphasize the interplay between mathematics, programming, and engineering principles.[5] A fragmented curriculum may also lead to limited exposure to hands-on experience and collaborative work—skills that are crucial for success in the AI industry.[6]

Consequently, students may graduate without the practical expertise required to succeed in real-world AI applications.[7] The importance of integrating STEM education has been well-documented, as it promotes critical thinking and problem-solving skills that are essential in the rapidly evolving tech landscape.[8] Furthermore, research indicates that students benefit from project-based learning experiences that allow them to apply theoretical knowledge in practical contexts.[9] This approach not only enhances understanding but also fosters a sense of ownership and engagement in the learning process.[10]

Moreover, the integration of AI technologies into STEM education can facilitate personalized learning experiences, adapting to individual student needs and learning styles.[11] This adaptability is particularly important in a field as complex as AI, where students may have varying levels of prior knowledge and experience.[12] By leveraging AI tools in the classroom, educators can create more inclusive learning environments that cater to diverse student populations.[13,14]

The Role of STEM Learning Projects

The concept of STEM learning projects offers a promising solution to these challenges. By integrating STEM subjects through project-based learning, students are provided with opportunities to work on interdisciplinary,

real-world problems that simulate the challenges faced in professional AI environments.[15] STEM learning projects allow students to apply theoretical knowledge to practical problems, thus enhancing their problem-solving and critical thinking skills.[16]

STEM learning projects also emphasize collaboration, an essential skill in the modern workforce. Working in teams enables students to engage in peer learning and develop communication and teamwork skills, which are highly valued by employers in the AI sector.[17] Moreover, these projects often require students to use a variety of tools and technologies, offering them hands-on experience with the software, programming languages, and methodologies commonly used in AI development.[18] This hands-on experience is crucial for preparing students to meet the demands of the industry, where practical skills are often as important as theoretical knowledge.[19]

Furthermore, research indicates that project-based learning fosters a deeper understanding of complex concepts by allowing students to explore and experiment in a supportive environment.[20] This experiential learning approach not only enhances knowledge retention but also cultivates a sense of ownership and motivation among students.[21] By engaging in collaborative projects, students can learn from one another, share diverse perspectives, and develop critical interpersonal skills that are essential for success in the AI field.[19]

In addition, STEM learning projects can bridge the gap between academia and industry by incorporating real-world challenges into the curriculum. This alignment with industry needs ensures that students are not only learning relevant content but are also prepared to tackle the specific challenges they will encounter in their careers.[22] By collaborating with industry partners, educational institutions can create project-based learning opportunities that reflect current trends and technologies in AI.[23]

Moreover, the integration of STEM learning projects into AI education can help address the existing gaps in traditional curricula, which often lack interdisciplinary approaches. By fostering connections between different STEM disciplines, students can develop a more holistic understanding of AI and its applications.[24] This interdisciplinary perspective is vital for solving complex problems that require knowledge from multiple fields, such as computer science, mathematics, and engineering.[25]

Research Objectives

This research focuses on designing and assessing the effectiveness of a STEM Learning Project model tailored for Artificial Intelligence (AI) courses in higher education. The main goal is to evaluate the impact of this model on students' engagement, problem-solving skills, and their ability to integrate interdisciplinary knowledge. By focusing on AI education, this study explores the potential of STEM learning projects in enhancing both technical skills, such as programming and algorithm design, and soft skills, including collaboration and communication, which are essential for future AI professionals.

This study also aims to explore the challenges and opportunities associated with incorporating STEM learning projects into AI courses. Gaining an understanding of these challenges will offer crucial insights for educators and policymakers seeking to modernize AI curricula and enhance educational quality. Such insights can contribute to the development of more engaging and effective learning environments, better equipping students for the rapidly advancing AI industry..

METHOD

Research Design

This study employs a mixed-methods research approach to evaluate the effectiveness of the STEM Learning Project model in AI courses. By integrating qualitative and quantitative methods, the research offers a holistic assessment of the model's influence on student engagement, problem-solving skills, and the integration of interdisciplinary knowledge.[26] The quantitative aspect of the study utilizes pre- and post-assessment surveys to evaluate changes in students' knowledge and levels of engagement. Meanwhile, the qualitative aspect involves conducting interviews and focus group discussions with both students and educators to delve into their experiences with STEM learning projects and gather their perspectives on the model's effectiveness.

A quasi-experimental design is employed for the quantitative phase of the study, where two groups of students—one that undergoes the STEM Learning Project model and a control group that follows the traditional AI curriculum—are compared. This allows for an analysis of the effectiveness of the STEM model relative to traditional teaching methods. The qualitative data collected will help to understand the reasons behind the quantitative findings, providing deeper insights into the students' and educators' perspectives.

Hypothesis

The primary hypothesis of this study is as follows:

a. H1: The implementation of the STEM Learning Project model in AI courses will significantly improve students' engagement, problem-solving skills, and the integration of knowledge across STEM disciplines.

b. H0: There will be no significant difference in students' engagement, problem-solving abilities, or knowledge integration between the STEM Learning Project model and traditional AI teaching methods.

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Data Collection Instrument

This study comprised 60 undergraduate AI students, who were divided into two groups: an experimental group that employed the STEM Learning Project model and a control group that adhered to a traditional curriculum. Participants were purposively selected based on their completion of prerequisite programming and mathematics courses, ensuring balanced demographics. The study spanned 12 weeks, beginning with pre-tests, transitioning to either project implementation or traditional lectures, and concluding with post-tests and qualitative evaluations through interviews and focus groups.

The STEM Learning Project's impact was evaluated using a combination of quantitative and qualitative data collection methods. Pre- and post-assessment surveys, consisting of 20 validated Likert-scale questions, were used to measure student engagement, problem-solving skills, and interdisciplinary knowledge integration. These surveys, administered online for convenience and confidentiality, were complemented by focus group discussions and semi-structured interviews. These qualitative instruments explored participants' experiences, challenges, and perceptions. Teacher feedback surveys provided insights into the model's effectiveness and implementation feasibility.

The data analysis utilized robust statistical techniques to ensure validity, including normality and homogeneity tests. Quantitative results were supported by qualitative findings, highlighting the experimental group's enhanced engagement and interdisciplinary learning compared to the control group. To ensure replicability, the methodology was meticulously detailed, encompassing experimental procedures, assessment tools, and thematic coding for qualitative data. Appendices will include survey instruments, project roadmaps, and coding manuals to facilitate replication, demonstrating the effectiveness of STEM-based learning in fostering interdisciplinary skills and practical AI applications.

STEM Learning Project Model Syntax

The process begins with formulating expected learning outcomes, which are essential for guiding the project's objectives and ensuring alignment with academic goals. These outcomes provide a clear framework for what students should achieve by the end of the STEM Learning Project, such as enhanced problem-solving skills, improved collaboration, and the application of interdisciplinary knowledge. Following this, application-based determination of group members takes place, where students are assigned to groups based on their skills and interests, fostering a balanced distribution of expertise and promoting effective teamwork. This step ensures that each group has a diverse range of abilities, which is crucial for tackling complex AI-related tasks within the project.

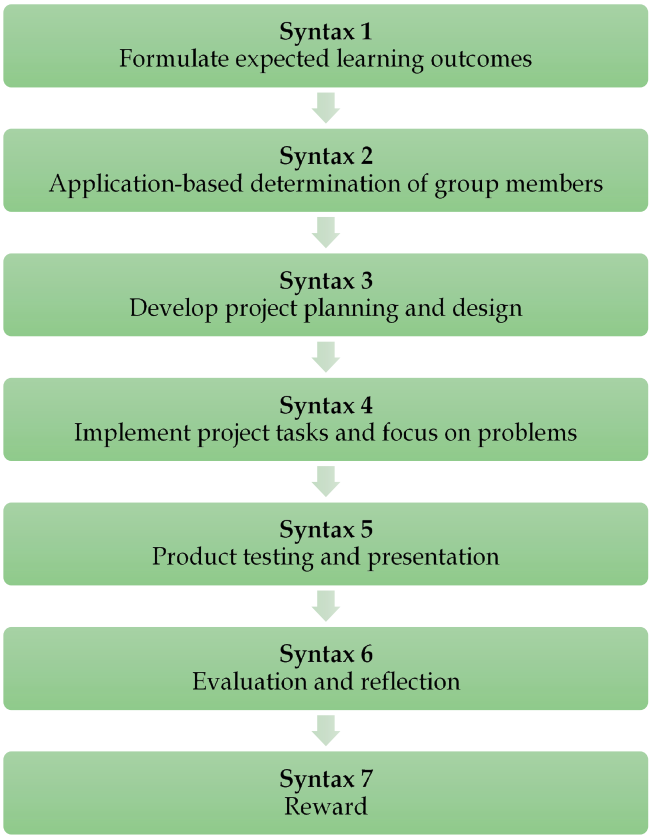

Figure 1. Framework of Case-Project Method and Building Information Modeling Integration

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Once the groups are formed, the next step involves developing project planning and design. Here, students outline their approach, set milestones, and assign tasks, ensuring that all members understand their responsibilities and the project's overall goals. As the project progresses, students begin to implement project tasks, focusing on problem-solving and applying theoretical knowledge to practical challenges. This phase is central to the learning experience, as students actively engage with real-world issues related to AI, testing their skills and creativity. The focus on solving specific problems encourages critical thinking and teamwork, which are essential in a collaborative learning environment.

After completing the project tasks, product testing and presentation follow. Students test their final products to ensure functionality and accuracy, followed by a presentation where they showcase their findings and solutions to the broader academic community or stakeholders. This stage emphasizes communication skills and the ability to effectively present technical information. Finally, evaluation and reflection take place, where both the students and instructors assess the project's outcomes, identifying successes and areas for improvement. The process concludes with a reward, where students are acknowledged for their efforts and achievements, reinforcing the value of their hard work and learning. This cycle not only reinforces academic learning but also provides motivation for continued development in future projects.

Data Analysis Techniques

It is proposed that the data collected from the pre-test, post-test, and other instruments developed will be analyzed using statistical techniques to test the proposed hypothesis. The study also utilizes a normality test, where the data will be checked for normal distribution before conducting the hypothesis tests. To assess normality, the Kolmogorov-Smirnov or Shapiro-Wilk test will be employed. Homogeneity Test: Before conducting the homogeneity test, the variances of the control and experimental groups will be compared. Levene's test of homogeneity of variance will be performed to assess the variance between the groups. Independent Sample t-Test: This test will be used to assess the magnitude of the difference between the experimental group and the control group following the post-test exercise. The purpose of this test is to determine whether the implementation of the STEM Learning Project model in Artificial Intelligence education produces an effectiveness of the proposed STEM Learning Project model in Artificial Intelligence (AI) courses at higher learning institutions. compared to traditional teaching methods.

RESULT AND DISCUSSION

STEM Learning Project Model Approach

Figure 2 illustrates the development of a guidebook for implementing the STEM Learning Project model in Artificial Intelligence education. This integration provides a comprehensive learning experience, aligning student skills with industry demands in AI. The guidebook emphasizes student involvement throughout the STEM Learning Project cycle, focusing on project planning, implementation, and the final presentation of AI-based projects.

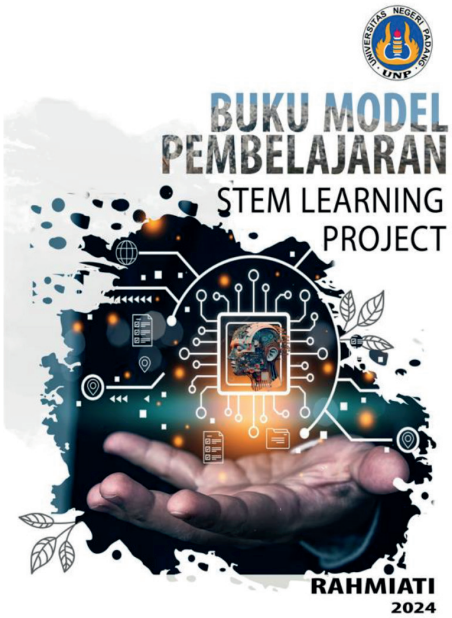

Figure 2. STEM Learning Project Handbook for Artificial Intelligence Course

Incorporating STEM aspects fosters collaboration, such as integrating scientific principles (Science), considering user interface and experience design (Art), and applying mathematical models for algorithm optimization. Beyond technical AI skills, the guidebook covers fundamental concepts such as machine learning algorithms, data analysis techniques, and ethical considerations in AI development. Additionally, it includes real-world case studies to enhance the conceptual understanding of AI applications in critical sectors and industrial projects.

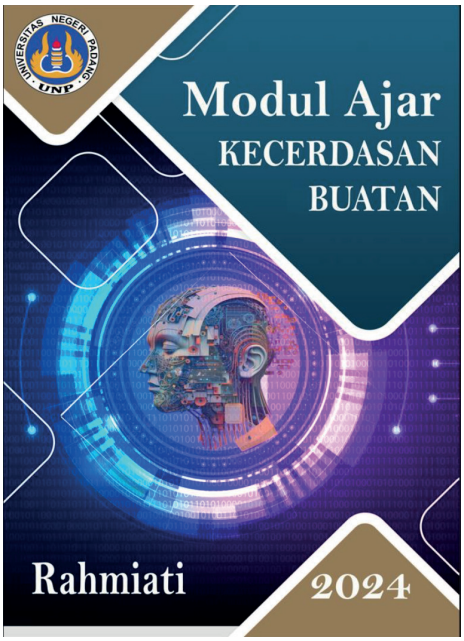

Figure 3. STEM Learning Project Approach Module

Figure 3 illustrates the outcomes of creating a project sheet designed to enhance students' 21st-century skills through a STEM-based learning approach. This process focuses on developing innovative AI solutions by integrating interdisciplinary knowledge. The project steps are as follows: 1) Science: Identifying real-world AI challenges, such as improving data accuracy or algorithm efficiency. 2) Technology: Applying AI methodologies while addressing ethical considerations, algorithmic efficiency, and system performance. 3) Engineering: Designing creative AI models and user interfaces using various tools and techniques. 4) Mathematics: Utilizing mathematical models to optimize algorithms, analyze data, and make precise predictions. 5) Engineering and Science: Evaluating AI models for accuracy, robustness, and scalability, and identifying areas for improvement. 6) Technology and Mathematics: Presenting project outcomes that integrate design concepts, AI implementation, model testing, and evaluation. This assignment aims to develop students' technical skills, creativity, problem-solving, innovation, and collaboration, while deepening their understanding of AI within the STEM framework.

Data Analysis and Findings

This study evaluates the effectiveness of the STEM Learning Project model in AI courses by analyzing both qualitative and quantitative data. The quantitative findings, obtained through pre- and post-assessment surveys, highlight significant improvements in students' knowledge, engagement, and interdisciplinary understanding of AI concepts. These results are reinforced by a comparative analysis between the experimental and control groups, with the STEM Learning Project group exhibiting more substantial progress than the group following the traditional AI curriculum. A descriptive analysis was conducted on the pre-test and post-test scores of both groups, and the results of this analysis are summarized in the accompanying table.

Table 1. Results of the descriptive analysis results for pre-test and post-test

Group	Mean Pre-Test Score	Mean Post-Test Score
Experiment	53,30	83,17
Control	45,74	74,95

According to the result tabulated in the table above, the experimental and control groups showed a similar

increase. The experimental group experienced an average increase of 29,87 with a pretest score of 53,30 and a posttest of 83,17. Meanwhile, the control group experienced a slightly smaller increase of 29,21 with a pretest score of 45,74 and a posttest of 74,95. Although there were differences in the magnitude of change between the two groups, the changes were quite similar, indicating that both groups experienced almost comparable improvements from pretest to posttest. Furthermore, the normality test was applied to determine the suitability of the data to inferential tests regarding the degree to which it was normally distributed. The results of the Kolmogorov-Smirnov test were used to determine the distribution of the data.

Table 2. Results of the Kolmogorv-Smirnov test

Group	Pre-Test (p-value)	Post-Test (p-value)
Experiment	0,200	0,081
Control	0,200	0,163

The results show that the data in both groups, for both pre-test and post-test, were normally distributed ($p > 0,05$). Levene's Test was used to examine the homogeneity of variances between the experiment and control groups.

Table 3. Results of Levene's Test

Variable	F	Sig. (p-value)
Pre-Test	1,507	0,150
Post-Test	0,909	0,507

The analysis indicates that the variances of the experiment group to the control group were similar ($p > 0,05$) suggesting that the groups could be compared parametrically. To establish the researching hypothesis the two condition Independent Sample T-Test was used to compare the post test results between the experimental and control groups.

Table 4. Results of T-Test

Test Type	Variable	t	Sig. (p-value)	Interpretation
Independent Sample T-Test	Pre-Test vs Post-Test	3,875	0,191	Significant difference between post-test scores of experiment and control goups; larger increase in the experiment group.

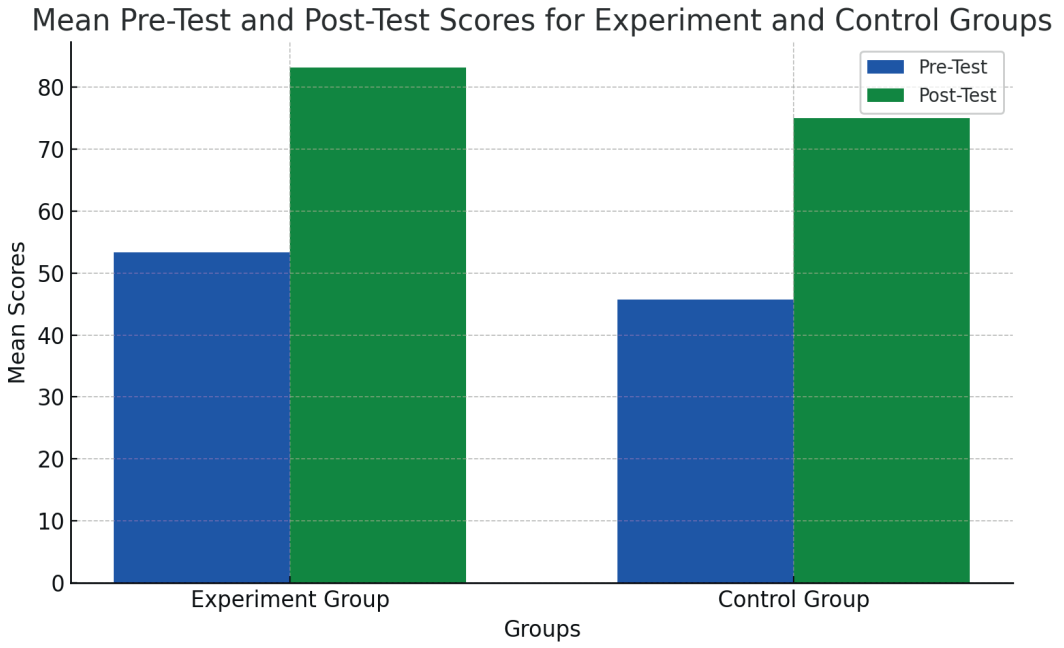

Figure 4. Pre-Test and Post-Test Scores

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DISCUSSION

This study aimed to assess the impact of the STEM Learning Project model on improving student outcomes in Artificial Intelligence (AI) courses at higher education institutions. The findings reveal notable enhancements in student engagement, problem-solving skills, and interdisciplinary integration of AI concepts. While both the experimental and control groups demonstrated progress between the pre-test and post-test, the experimental group achieved slightly greater improvements. The observed score increases in both groups indicate that integrating project-based learning within the STEM framework significantly enriches students' educational experiences. These results align with prior studies highlighting the effectiveness of practical, interdisciplinary learning methods in STEM education.[16]

The results from the pre-test and post-test analysis are consistent with existing research, which highlights that project-based learning (PBL) fosters cognitive growth and student engagement. The experimental group, which implemented the STEM Learning Project model, demonstrated a higher increase in post-test scores (29,87) compared to the control group (29,21). These findings reinforce the idea that active involvement in project-based activities promotes better knowledge retention and the practical application of concepts. This is particularly significant in disciplines like AI, where the integration of interdisciplinary skills is essential.[19,27] Additionally, the normality test results indicate that the data for both groups were normally distributed, suggesting that inferential statistical tests, such as the independent sample t-test, could be appropriately applied to compare the results.

The Levene's test for homogeneity of variances further corroborated the suitability of conducting parametric tests by showing that both groups had similar variances. This finding is consistent with prior studies on PBL, where homogeneous variances across groups support valid comparisons of group performance in experimental and control settings.[27] As noted in the results, the homogeneity of variance between the experimental and control groups enabled the use of the independent sample t-test to assess differences in post-test scores.

The significant difference in post-test scores between the experimental and control groups, as indicated by the independent sample t-test (t = 3,875, p = 0,191), highlights the effectiveness of the STEM Learning Project model in AI education. This result is consistent with the work of [28], who found that integrating project-based learning into STEM education fosters critical thinking, problem-solving, and collaboration skills—skills that are essential for AI development. Furthermore, the STEM Learning Project model's emphasis on interdisciplinary integration, combining science, technology, engineering, and mathematics, supports the notion that real-world applications of AI concepts improve students' ability to apply theoretical knowledge.[29,30,31]

The inclusion of real-world case studies, as shown in the guidebook for the STEM Learning Project model, also played a crucial role in improving students' conceptual understanding of AI applications in critical sectors. This approach is in line with findings from previous studies, which suggest that applying STEM concepts to real-world problems enhances both technical and soft skills, including creativity, innovation, and collaboration.[32] In this study, students' ability to engage with complex, industry-relevant AI problems likely contributed to their higher post-test scores and improved interdisciplinary knowledge integration.

While both the experimental and control groups showed improvement, the slightly higher gain in the experimental group suggests that active learning methods, as promoted by the STEM Learning Project model, offer additional benefits in AI education. This is supported by prior research that indicates project-based, active learning approaches lead to greater motivation and engagement in STEM fields.[33] As AI continues to evolve as a field, these findings suggest that integrating a STEM-based approach into AI education will be essential for preparing students for the complex and collaborative nature of AI-related industries.

In conclusion, this study provides compelling evidence that the STEM Learning Project model is an effective pedagogical tool in enhancing student achievement in AI education. The findings indicate that project-based learning models that emphasize interdisciplinary collaboration and real-world problem-solving significantly improve students' cognitive, affective, and psychomotor skills. Given the increasing demand for AI professionals with strong interdisciplinary skills, the integration of STEM learning projects into AI curricula offers a promising avenue for fostering both the technical expertise and soft skills necessary for success in this rapidly advancing field.

CONCLUSION

This study highlights the effectiveness of the STEM Learning Project model in improving student learning outcomes in Artificial Intelligence (AI) courses at higher education institutions. The findings reveal that students in the experimental group, who participated in the STEM Learning Project, demonstrated greater advancements in post-test scores compared to those in the control group. These results emphasize the critical role of active learning, interdisciplinary integration, and practical problem-solving in AI education. By leveraging project-based learning within the STEM framework, the model enhances students' cognitive, affective, and psychomotor abilities, which are vital for building competencies required in the AI field. The positive outcomes observed in this study align with prior research on STEM-based project learning, which consistently highlights

its potential to cultivate critical thinking, problem-solving, and teamwork skills. The validation of pre- and post-test findings, supported by normality and homogeneity assessments, affirms the effectiveness of this approach in boosting both student engagement and academic achievements. The significant differences in post-test performance between the experimental and control groups further substantiate the conclusion that embedding STEM learning projects into AI curricula yields measurable educational benefits. In summary, this research demonstrates that adopting the STEM Learning Project model in AI education substantially enhances students' knowledge and interdisciplinary capabilities. Given the rising demand for AI professionals equipped with technical expertise and strong collaborative skills, the study provides valuable evidence of the advantages of STEM-based methodologies in preparing students for the dynamic requirements of the AI industry. Future studies could investigate the long-term effects of this model on career readiness and its applicability to other technology-driven educational fields.

REFERENCES

1. Eshaq HA. The Effect of Using STEM Education on Students Mathematics Achievement. Journal of Pedagogical Research. Epub ahead of print 2023. DOI: 10.33902/jpr.202423476.

2. Nağaç M, Kalayci S. The Effect of STEM Activities on Students' Academic Achievement and Problem Solving Skills: Matter and Heat Unit. E-Kafkas Eğitim Araştırmaları Dergisi 2021; 8: 480–498.

3. Lee H, Cheng Y, Wang W, et al. Exploring the Learning Process and Effectiveness of STEM Education via Learning Behavior Analysis and the Interactive-Constructive- Active-Passive Framework. Journal of Educational Computing Research 2023; 61: 951–976.

4. Chang C-C, Chen Y. Educational Values and Challenges of I-Stem Project-Based Learning: A Mixed-Methods Study With Data-Transformation Design. Front Psychol; 13. Epub ahead of print 2022. DOI: 10.3389/fpsyg.2022.976724.

5. Costa MC, Domingos A, Teodoro VD, et al. Teacher Professional Development in STEM Education: An Integrated Approach With Real-World Scenarios in Portugal. Mathematics 2022; 10: 3944.

6. Chedup S, Subba B, Utha K, et al. Importance of Modern Stem Technologies for Transformation of Stem Education in the Grassroots Level: an Experimental Study in Bhutan. Journal of Applied Engineering Technology and Management 2023; 3: 1–9.

7. Budiyanto CW, Fenyvesi K, Lathifah A, et al. Computational Thinking Development: Benefiting From Educational Robotics in STEM Teaching. European Journal of Educational Research 2022; volume-11-2022: 1997–2012.

8. Stonier F, Adarkwah MA. Impact of STEM Professional Development Sessions on Chinese Pre-Service Early Childhood Teachers. International Journal of Stem Education for Sustainability 2023; 3: 68–93.

9. Karimah F, Wulandari F. The Influence of an Integrated STEM Project-Based Learning Toward Science Literacy Abilities Students in Elementary School. Jurnal Penelitian Pendidikan Ipa 2023; 9: 10446–10456.

10. Rochim RA, Prabowo P, Budiyanto M, et al. The Use of STEM-Integrated Project-Based Learning Models to Improve Learning Outcomes of Junior High School Students. Epub ahead of print 2022. DOI: 10.2991/assehr.k.211229.034.

11. Amelia R, Santoso SB. 21st Century Skills in Project Based Learning Integrated STEM on Science Subject: A Systematic Literature Review. Epub ahead of print 2021. DOI: 10.2991/assehr.k.210421.085.

12. Peters-Burton EE, House A, Peters V, et al. Understanding STEM-focused Elementary Schools: Case Study of Walter Bracken STEAM Academy. Sch Sci Math 2019; 119: 446–456.

13. Yulkifli Y, Yohandri Y, Azis H. Development of Physics E-Module Based on Integrated Project-Based Learning Model With Ethno-Stem Approach on Smartphones for Senior High School Students. Momentum Physics Education Journal 2022; 93–103.

14. Martínez-Plumed F, Gómez E, Hernández-Orallo J. Futures of artificial intelligence through technology

readiness levels. Telematics and Informatics; 58. Epub ahead of print 2021. DOI: 10.1016/j.tele.2020.101525.

15. Shofiyah N, Wulandari F, Mauliana MI, et al. Teamwork Skills Assessment for STEM Project-Based Learnig. Jurnal Penelitian Pendidikan Ipa 2022; 8: 1425–1432.

16. Yuliardi R. STEM Highlights: Principles, Frameworks and Implementation Strategies in Improving Scientific Literacy. International Journal on Emerging Mathematics Education 2022; 6: 119.

17. Dare EA, Ellis JA, Roehrig GH. Understanding Science Teachers' Implementations of Integrated STEM Curricular Units Through a Phenomenological Multiple Case Study. Int J STEM Educ; 5. Epub ahead of print 2018. DOI: 10.1186/s40594-018-0101-z.

18. Razia B, Awwad B, Taqi N. The Relationship Between Artificial Intelligence (AI) and Its Aspects in Higher Education. Development in Learning Organizations an International Journal 2022; 37: 21–23.

19. AL-Ghamdi ASA, Ragab M, Sabir MFS. Enhanced Artificial Intelligence-Based Cybersecurity Intrusion Detection for Higher Education Institutions. Computers Materials & Continua 2022; 72: 2895–2907.

20. Sanasintani S. Revitalizing the Higher Education Curriculum Through an Artificial Intelligence Approach: An Overview. J Social Science Utilizing Tech 2023; 1: 239–248.

21. Qolamani KIB. The Digital Revolution in Higher Education: Transforming Teaching and Learning. Qalamuna Jurnal Pendidikan Sosial Dan Agama 2023; 15: 837–846.

22. Muliyati D. Development of STEM Project-Based Learning Student Worksheet for Physics Learning on Renewable Energy Topic. J Phys Conf Ser 2023; 2596: 012078.

23. Pardamean B, Suparyanto T, Cenggoro TW, et al. AI-Based Learning Style Prediction in Online Learning for Primary Education. Ieee Access 2022; 10: 35725–35735.

24. Mudinillah A. Understanding Technological Trends in Education: How Artificial Intelligence Helps Learning in Colleges in Susta. J Emerging Technologies in Education 2023; 1: 47–58.

25. Nagaraj BK. The Emerging Role of Artificial Intelligence in STEM Higher Education: A Critical Review. International Research Journal of Multidisciplinary Technovation 2023; 1–19.

26. Creswell JW,, Creswell JD. Research design: Qualitative, quantitative, and mixed methods approaches. . Sage publications.

27. Hanif S, Wijaya AFC, Winarno N. Enhancing Students' Creativity Through STEM Project-Based Learning. Journal of Science Learning 2019; 2: 50.

28. Hakim LL, Sulastri YL, Mudrikah A, et al. STEM Project-Based Learning Models in Learning Mathematics to Develop 21st Century Skills. Epub ahead of print 2019. DOI: 10.4108/eai.19-10-2018.2281357.

29. Amelia R, Santoso SB. 21st Century Skills in Project Based Learning Integrated STEM on Science Subject: A Systematic Literature Review. Epub ahead of print 2021. DOI: 10.2991/assehr.k.210421.085.

30. Parrales Mendoza DG, Hernández Dávila CA, Moyota Paguay AR, Allauca Pancho FR. Teaching strategies based on augmented reality for the understanding of theorems and proofs in mathematics courses for higher education students. Salud, Ciencia y Tecnología. 2024;4:1279.

31. Ruiz Muñoz GF, Yépez González DA, Romero Amores NV, Cali Proaño Ángela F. Augmented reality's impact on STEM learning. Salud, Ciencia y Tecnología. 2024;4:1202.

32. Lee H, Cheng Y, Wang W, et al. Exploring the Learning Process and Effectiveness of STEM Education via Learning Behavior Analysis and the Interactive-Constructive- Active-Passive Framework. Journal of Educational Computing Research 2023; 61: 951–976.

33. Nağaç M, Kalayci S. The Effect of STEM Activities on Students' Academic Achievement and Problem

Solving Skills: Matter and Heat Unit. E-Kafkas Eğitim Araştırmaları Dergisi 2021; 8: 480–498.

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