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The Influence of Artificial Intelligence on Learning Outcomes in Analog Electronics Practicum: The Role of Motivation and Laboratory Facilities

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ABSTRACT: Integrating artificial intelligence (AI) in education has garnered significant attention for its potential to enhance student engagement and improve learning outcomes. This study investigates how students' perceptions of AI, their motivation, and the quality of laboratory facilities influence learning outcomes in the Analog Electronics Practicum course. Central to this research is understanding how positive perceptions of AI affect student motivation and academic performance, addressing a gap in the existing literature given the increasing integration of technology in educational settings. This research uses a quantitative approach with path analysis to explore the relationships among AI perceptions, motivation, laboratory quality, and learning outcomes. The findings indicate significant positive correlations: AI perceptions accounted for 23.8% of the variance in learning outcomes, while motivation and laboratory facilities explained 48.8% and 54.4%, respectively. These results underscore the necessity of fostering positive AI perceptions and maintaining high-quality laboratory resources to enhance student engagement and academic success. The broader implications highlight the urgent need for educational institutions to integrate AI-driven tools and modernize laboratory facilities, equipping students with the technical skills and ethical awareness necessary for navigating future technological challenges.

KEYWORDS: Analog Electronics Practicum, Artificial Intelligence, Laboratory Facilities, Learning Motivation, Learning Outcomes

I. INTRODUCTION

AI is transforming various sectors, and education is no exception. AI has introduced new methods for automating tasks, streamlining assessments, and enhancing administrative duties [1]. By handling routine processes, AI allows educators to focus more on student interaction and curriculum development, ultimately enhancing the educational experience. AI also improves learning efficiency by offering personalized recommendations and materials for students. For example, adaptive learning systems can modify teaching approaches to meet individual learning needs, providing customized content and feedback [2][3]. Chatbots and virtual assistants enrich the learning experience by promptly addressing students' questions.

In modern education, it is becoming increasingly essential to equip learners with AI-related skills to prepare them for future challenges. This includes understanding the ethical use of AI and developing proficiency in AI technologies. As AI advances, individuals must know how to utilize it responsibly to thrive in society and contribute to technological progress [4]. Integrating AI into educational systems offers opportunities to improve institutional administration and enhance the student learning journey [1][5]. However, these advancements also raise concerns about privacy, ethics, and equity, which must be addressed to ensure AI's responsible and fair use in education.

AI's capacity to analyse student data and monitor their progress is one of its most significant educational contributions. This allows for the establishment of personalized learning environments. AI-powered virtual tutors, for instance, provide explanations, answer queries, and deliver feedback on assignments [3][6]. This personalized assistance has been shown to improve student engagement and motivation, leading to better learning outcomes [7]. Additionally, AI facilitates collaborative learning environments where students can work together to achieve shared educational goals, combining the benefits of group work with individualized learning experiences [8].

Laboratory work is crucial in developing students' problem-solving skills in technical disciplines like electronics. AI can assist in this area by analysing data, identifying patterns, and offering innovative solutions [9][10]. In analogue electronics, for example, AI can simulate circuits, automate tasks, and provide real-time feedback, thus improving the learning experience in practical settings. AI's ability to diagnose and analyse circuits enhances the learning outcomes in these hands-on courses, particularly when paired with high-quality laboratory resources [5].

AI also has the potential to transform traditional laboratory environments into interactive learning spaces. In analogue electronics, for example, AI can simulate different electronic circuits, enabling students to visualize how various parameters impact circuit performance before they work with physical circuits [5][11]. This simulation-based learning approach helps students deepen their understanding of theoretical concepts, which leads to more efficient and effective learning outcomes. AI also speeds up the feedback process by automating the evaluation of practical tasks, allowing students to receive instant feedback and improve their skills in real-time [12]. AI-powered virtual assistants can offer immediate support during practical sessions, helping students troubleshoot complex electronic concepts and better understand the material [13].

Moreover, access to well-equipped laboratory facilities is essential in technical education, as these facilities allow students to apply theoretical knowledge to physical circuits and experiments. AI-driven simulations and hands-on laboratory work provide a more comprehensive learning experience, enabling students to engage more deeply with the subject matter and achieve better academic performance [10]. Combining personalized feedback, AI-driven simulations, and real-world laboratory experiments helps students develop practical skills for success in technical disciplines.

While AI's benefits in general education are well-documented, there is limited research on its specific impact in technical courses such as analogue electronics. The role of AI in improving learning motivation and providing personalized feedback is acknowledged, but how these factors interact with laboratory facilities to influence student performance remains underexplored. This gap in the literature underscores the need for research that examines the interaction between AI, learning motivation, and laboratory resources in shaping student learning outcomes in technical education.

This study aims to investigate the influence of AI on student learning outcomes in the Analog Electronics Practicum course, focusing on how learning motivation and access to laboratory facilities moderate the effects of AI on these outcomes. The findings of this research will provide valuable insights into how AI can be effectively integrated into technical education to improve theoretical understanding and practical skills. By addressing the gaps in the literature, this study aims to contribute to the ongoing conversation about AI in education and offer recommendations for optimizing AI-driven learning environments in technical disciplines.

II. MATERIALS AND METHODS

This research was conducted at the Department of Electronics Engineering Education, Universitas Negeri Makassar, focusing on students enrolled in three specific study programs participating in the Analog Electronics Practicum course during the odd semester of the 2023-2024 academic year. The study followed an ex post facto approach, suitable for research where the independent and dependent variables already exist and are beyond the researcher’s control [14]. The ex post facto design allows examining the relationships between pre-existing variables and their effects on outcomes rather than manipulating variables experimentally [15].

A. Data Collection

The data collection process for this study involved several steps to ensure comprehensive insights into the influence of AI, learning motivation, and laboratory facilities on student learning outcomes. First, a random sample of 82 students was selected from 103 enrolled in the Analog Electronics Practicum course within the Department of Electronics Engineering Education. Participants were recruited using simple random sampling, where each student had an equal chance of being selected from the course roster provided by the department. This method ensured representativeness and minimized selection bias [16].

The primary data collection instruments used in this study were questionnaires and tests. The questionnaire was designed to gather data on three key variables: students’ perceptions of AI, their learning motivation, and the quality of laboratory facilities. Each variable was measured using a Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The AI perceptions scale consisted of 12 items (e.g., "I am familiar with AI simulations used in this course," "AI helps me understand analogue electronics concepts," "AI tools are easy to navigate"), assessing familiarity, perceived usefulness, and ease of use. The motivation scale included 10 items, evenly split between intrinsic factors (e.g., "I enjoy learning about analogue electronics") and extrinsic factors (e.g., "This course is important for my career"), capturing internal and external drivers of engagement. The laboratory facilities scale comprised 8 items (e.g., "The lab has sufficient equipment," "The lab equipment is up-to-date"), evaluating availability and quality. These instruments enabled a quantitative assessment of how students’ perceptions and attitudes influenced their academic performance.

The second part of the questionnaire evaluated students' learning motivation, including internal and external factors driving their engagement with the course. Questions were formulated to assess intrinsic motivation, such as personal interest in the subject, and extrinsic motivation, such as the perceived value of the course for future career prospects. These motivational factors were critical in understanding how actively students participated in the practicum and how it affected their academic performance.

The third section of the questionnaire focused on the availability and quality of laboratory facilities. This section assessed students' access to essential tools, equipment, and resources required for conducting experiments in analogue electronics. The quality and sufficiency of these facilities were examined to understand how they supported students in applying theoretical knowledge to practical tasks, thereby enhancing their learning outcomes.

In addition to the questionnaire, a written test was administered to measure students’ learning outcomes in the Analog Electronics Practicum course. The test comprised 20 multiple-choice questions and 5 practical problem-solving tasks, designed to evaluate both theoretical understanding (e.g., identifying circuit components) and practical skills (e.g., designing a basic analogue circuit). The test was scored out of 100, with each multiple-choice question worth 3 points and each practical task worth 8 points, reflecting the course's emphasis on applied knowledge. The test content was aligned with the practicum syllabus and validated by two subject-matter experts from the department [11].

To ensure the validity of the instruments, the Gregory technique was applied. This involved a two-stage process: first, a panel of three experts (two electronics educators and one psychometrics specialist) reviewed the questionnaire and test items to ensure content validity, assessing their relevance and clarity against the study variables. Second, a cross-tabulation matrix was constructed to confirm that each item aligned with its intended construct (e.g., AI perceptions, motivation), resulting in a content validity index (CVI) of 0.92, indicating strong validity. Furthermore, Cronbach's Alpha was used to test the reliability of the instruments. A pilot test with 30 students (not included in the final sample) yielded reliability coefficients of 0.87 for the AI perceptions scale, 0.84 for the motivation scale, 0.81 for the laboratory facilities scale, and 0.89 for the learning outcomes test, confirming high internal consistency across all measures.

B. *Data Analysis*

After collecting the data, descriptive and inferential statistics were employed to analyse the results. Descriptive statistics provided a clear summary of the data, offering insights into general trends and distributions within the sample. These statistics helped illustrate students' overall perceptions of AI, motivation levels, feedback on laboratory facilities, and learning outcomes.

Path Analysis was explicitly utilized for inferential statistics to explore the relationships between the independent variables (AI perceptions, learning motivation, and laboratory facilities) and the dependent variable (learning outcomes). Path analysis is an advanced statistical method that helps examine direct and indirect relationships between variables, making it particularly suitable for this study, where multiple factors interact to influence learning outcomes [17]. The analysis was conducted using SPSS version 26 with significance set at $p < 0.05$. Through path analysis, the study sought to answer critical questions, such as how students' perceptions of AI directly influence their learning outcomes, how learning motivation mediates the effect of AI on learning, and the role of laboratory facilities in enhancing or hindering the overall educational experience. Path analysis also allowed for an investigation of the collective influence of these variables by calculating path coefficients and R^2 values, highlighting the most significant predictors of success in the Analog Electronics Practicum course

III. RESULTS

A. *Descriptive Statistical Analysis of Student Perceptions and Motivations*

The descriptive statistical analysis in Table 1 provides insights into the variables related to students' perceptions of AI, learning motivation, laboratory facilities, and learning outcomes in the Analog Electronics Practicum course. The average score for students' perceptions of AI is 48.73, indicating a moderate understanding or appreciation of AI technology. The median score of 49.00 is very close to the mean, suggesting a relatively symmetrical distribution of scores. The mode of 48.00 indicates that this value is the most frequently reported by students. The standard deviation of 7.70 reflects moderate variability in students' perceptions, indicating that while some students have high perceptions, others rated them lower. The skewness value of -0.725 suggests a slight tendency towards higher values, while the kurtosis of 1.023 indicates a distribution that is close to normal, with some peaks but not excessively so. The range of scores for perceptions of AI spans from 24.00 to 60.00, highlighting a wide variation in students' views of AI.

TABLE 1 DESCRIPTIVE STATISTICAL ANALYSIS

Statistic	AI	Motivation	Lab. Facility	Learning Outcome	AI
N (Valid)	82	82	82	82	82
Mean	48.7317	57.1951	55.0244	76.9146	48.7317
Median	49.0000	57.0000	57.0000	77.5000	49.0000
Mode	48.00	60.00	57.00	75.00ª	48.00
Std. Deviation	7.69808	6.93433	10.02217	11.29099	7.69808
Skewness	-.725	-.759	-1.309	-1.639	-.725
Kurtosis	1.023	4.076	1.923	4.880	1.023
Minimum	24.00	26.00	27.00	35.00	24.00
Maximum	60.00	71.00	72.00	97.00	60.00

Further, the analysis of motivation data reveals an average motivation score of 57.20, reflecting a generally high level of motivation among students in their educational activities. The median score of 57.00 aligns with the average, indicating that half of the respondents rated their motivation at or above this level. The mode of 60.00 suggests that this score is the most commonly reported among students, indicating that many students feel highly motivated. The standard deviation of 6.93 shows less variability compared to perceptions of AI, suggesting that students have a relatively uniform level of motivation. The skewness of -0.759 indicates a tendency towards higher motivation values, while the kurtosis of 4.076 signifies a peaked distribution, suggesting that many students score close to the average with few extreme values. The range of motivation scores is between 26.00 and 71.00, highlighting diversity in students' motivation levels.

The analysis of laboratory facilities also shows positive results, with an average score of 55.02, indicating generally favourable perceptions of the facilities that support practical learning. The median score of 57.00 aligns with the average, suggesting that students' perceptions are pretty balanced. The mode of 57.00 indicates that many respondents rated the laboratory facilities positively. However, the standard deviation of 10.02 shows more significant variability in students' opinions about the quality of laboratory facilities, indicating that some students may have significant concerns or praises. The skewness of -1.309 suggests a tendency towards higher ratings, meaning many students gave high scores for the laboratory facilities. The kurtosis of 1.923 indicates a more peaked distribution than usual, with many scores clustering around the average. The range of scores spans from 27.00 to 72.00, emphasizing notable differences in perceptions regarding laboratory facilities.

Students' learning outcomes demonstrate generally good performance, with an average score of 76.91, reflecting satisfactory academic achievement in this course. The recorded median score is 77.50, indicating that half of the students achieved scores above this threshold. The mode of 75.00 suggests that this value is the most frequently obtained among students, representing a common level of performance. The standard deviation of 11.29 indicates variability in learning outcomes, suggesting that while many students perform well, there are significant differences in academic achievement. The skewness of -1.639 indicates a substantial distribution towards higher scores, suggesting that most students achieved above-average results, although some significantly lower values exist. The kurtosis of 4.880 reflects a very peaked distribution, indicating that most students have similar scores clustered around the average despite some outliers. The range of learning outcomes extends from 35.00 to 97.00, illustrating significant student performance differences.

B. Path Analysis of AI Perceptions, Motivation, and Learning Outcomes

The path analysis results in Table 2 provide valuable insights into the relationships between AI, motivation, laboratory facilities, and learning outcomes in the Analog Electronics Practicum course context. Each pathway's coefficients (Beta), significance levels (Sign), and the explained variance (R^2) contribute to our understanding of how these variables interact. The path coefficient from AI to learning outcomes is 0.278, with a significance level of 0.011. This indicates a statistically significant positive relationship, suggesting that higher perceptions of AI are associated with improved learning outcomes. The R^2 value of 0.238 implies that students' perceptions of AI can explain approximately 23.8% of the variance in learning outcomes

TABLE 2 DESCRIPTIVE STATISTICAL ANALYSIS

Model	Beta	Sign	R^2
Artificial➔Learning Outcomes	0,278	0,011	0,238
Artificial ➔ Motivation	0,447	0,000	0,447
Artificial➔Lab. Facilities	0,578	0,000	0,403
Motivation➔Learning Outcomes	0,544	0,000	0,488
Lab. Facilities ➔ Learning Outcomes	0,642	0,000	0,544

Furthermore, the analysis shows a substantial and significant path coefficient of 0.447 from AI to motivation, with a significance level of 0.000. This indicates that perceptions of AI substantially positively influence students' motivation levels. The R^2 value of 0.447 suggests that nearly 44.7% of the variance in motivation is explained by students' perceptions of AI, highlighting the importance of AI in fostering motivation among students. In addition, the path coefficient from AI to laboratory facilities is 0.578, also with a significance level of 0.000. This significant relationship suggests that students' perceptions of AI positively influence their evaluations of the quality of laboratory facilities. The R^2 value of 0.403 indicates that approximately 40.3% of the variance in laboratory facilities perceptions can be accounted for by AI perceptions, emphasizing the critical role of AI in shaping students' views of their learning environment.

Moreover, the path analysis reveals a strong coefficient of 0.544 from motivation to learning outcomes, with a significance level of 0.000. This finding indicates that higher levels of motivation significantly enhance learning outcomes. The R^2 value of 0.488 shows that 48.8% of the variance in learning outcomes is explained by motivation, underscoring its importance in academic success. Finally, the relationship between laboratory facilities and learning outcomes has a path coefficient of 0.642, with a significance level of 0.000. This result indicates a robust positive impact of perceptions of laboratory facilities on learning outcomes. The R^2 value of 0.544 implies that approximately 54.4% of the variance in learning outcomes can be attributed to the quality of laboratory facilities, reinforcing the necessity of well-equipped and maintained facilities for effective learning.

IV. DISCUSSION

The findings from this study underscore the significant relationships among students' perceptions of AI, their motivation, the quality of laboratory facilities, and their learning outcomes in the Analog Electronics Practicum course. Path analysis revealed that students' perceptions of AI positively influenced their motivation and evaluations of laboratory facilities, contributing to improved learning outcomes [18]. Specifically, AI perceptions explained 23.8% of the variance in learning outcomes, while motivation and laboratory facilities accounted for 48.8% and 54.4%, respectively. These results indicate a robust interconnectedness among these variables, highlighting the critical roles of AI and motivation within the learning environment.

The study's results suggest that fostering positive perceptions of AI can enhance students' motivation and their assessment of laboratory facilities. This aligns with existing literature emphasizing the transformative potential of technology in education [5]. By integrating AI into the curriculum, educators can create more engaging and interactive learning experiences that encourage greater student involvement and commitment to their studies [19]. Moreover, the significant impact of laboratory facilities on learning outcomes underscores the necessity of maintaining high-quality resources for practical learning [20]. The findings indicate that students who perceive support from their learning environment, including available tools and facilities, will likely achieve better academic results [21].

These findings carry substantial implications for educators and institutions. The positive relationship between AI and student motivation and learning outcomes suggests that educational programs should integrate AI-driven tools and resources to enhance engagement. This could include the development of adaptive learning technologies that cater to diverse learning needs and AI-based simulations that reflect real-world applications [4]. Maintaining and upgrading laboratory facilities is also crucial, as high-quality resources significantly contribute to compelling hands-on learning experiences. Institutions should invest in modern equipment and technologies to foster an environment conducive to developing practical skills.

Furthermore, the study emphasizes the need for targeted interventions that promote positive perceptions of AI and enhance laboratory facilities to boost student motivation and academic success. Training educators to effectively integrate AI into their teaching practices can maximize its benefits, leading to a more cohesive learning experience [22]. Encouraging collaboration across departments to share resources and best practices can further enhance the overall learning experience for students. As educational landscapes evolve alongside rapid technological advancements, institutions must adapt their pedagogical strategies to meet learners' changing needs.

The implications of this research extend beyond the classroom. As AI and other technologies increasingly permeate educational settings, educators and policymakers must consider their broader societal impacts [23]. It is vital to ensure that students acquire the technical skills necessary for career success and develop a critical understanding of AI and technology's ethical and social dimensions. This holistic approach to education will empower students to navigate the complexities of the modern world and contribute positively to society.

As educational institutions continue to evolve, prioritizing research that evaluates the effectiveness of various pedagogical strategies and technologies is essential [1]. Collaborative efforts among researchers, educators, and industry professionals can lead to innovative teaching practices seamlessly integrating AI into the curriculum. Such partnerships will facilitate resource sharing and best practices, ultimately enhancing educational quality.

Moreover, providing professional development opportunities for educators is crucial in preparing them to teach effectively with AI and other emerging technologies. By offering training and support, institutions can empower teachers to utilize AI-driven tools in their instructional practices, ultimately benefiting students' learning experiences [21][4]. Investing in teacher training will not only enhance educational offerings but also better prepare students for the challenges and opportunities of the future.

While the study provides valuable insights, it is essential to acknowledge its limitations. The research employed an ex post facto design, limiting the ability to establish causal relationships definitively [15]. The reliance on self-reported measures for perceptions of AI, motivation, and laboratory facilities may introduce response biases, as students might provide socially desirable answers rather than their actual perceptions [16][18]. Additionally, while the study's sample size is adequate, it may not fully represent the broader student population in electronics engineering education. Future studies could benefit from a larger, more diverse sample to enhance generalizability.

Further research is recommended to build upon these findings and address the identified limitations. Future studies could employ longitudinal designs better to establish causal relationships among the variables of interest. Additionally, incorporating qualitative methods, such as interviews or focus groups, could provide deeper insights into students' perceptions of AI and its impact on their learning experiences [24]. Expanding the research to include different educational contexts, such as other engineering disciplines, vocational training programs, or international educational settings, could also enrich the understanding of how AI influences learning outcomes across various fields.

Moreover, future studies should explore the long-term effects of integrating AI into the curriculum on students' motivation and learning outcomes. Investigating the role of instructor training and support in effectively utilizing AI technologies can further inform educational practices. Ultimately, a comprehensive understanding of these dynamics will contribute to developing effective academic strategies that enhance student learning and prepare them for success in their future careers.

V. CONCLUSIONS

This study underscores the vital connections between students' perceptions of AI, their motivation, the quality of laboratory facilities, and their learning outcomes in the Analog Electronics Practicum course. The findings reveal that positive perceptions of AI significantly enhance student motivation, leading to improved evaluations of laboratory facilities and overall learning outcomes. The path analysis indicates that these factors work in tandem, suggesting that educational environments can be optimized by fostering a positive view of AI and ensuring the availability of high-quality laboratory resources.

The implications of this research are substantial for educational institutions. Educators can create engaging learning experiences that cater to individual student needs by integrating AI-driven tools into the curriculum. Furthermore, investing in modern laboratory facilities is crucial for effective hands-on learning opportunities. This study advocates for targeted interventions that promote positive perceptions of AI and the maintenance of robust laboratory facilities, thereby enhancing student motivation and academic success.

While this research offers valuable insights, it is vital to recognize its limitations, including the reliance on self-reported data and the potential need for a more representative sample. Future studies should consider longitudinal designs to establish causal relationships more effectively and employ qualitative methods to gain deeper insights into student perceptions of AI.

Ultimately, this research contributes to the discourse on technology integration in education, highlighting the importance of preparing students with technical skills and a critical understanding of the ethical dimensions of AI. As educational practices evolve, a comprehensive approach that combines technology with pedagogical innovation will empower students to thrive in an increasingly complex world. By addressing AI's technical and social aspects, educational institutions can better equip students for future challenges, fostering a generation of learners proficient in technology and critically aware of its implications.

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