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Reclaiming Cognitive Skills in Electrical Technology: Addressing AI Dependence in South African Technical Schools

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ABSTRACT

This study investigated the growing dependence on artificial intelligence (AI) tools among learners studying electrical technology in South African technical schools and its influence on cognitive and critical thinking skills. The purpose of this study was to examine how excessive dependence on AI affects learners' problem-solving skills and practical competence, which are important for meeting the demands of the Electrical Technology curriculum and the broader technical industry in South Africa. A quantitative research approach was adopted using a descriptive survey design. Simple random sampling was used to select 120 electrical technology learners from four technical high schools across Gauteng Province, South Africa. The data were collected using structured questionnaires and online surveys focusing on learners' use of AI, engagement in problem-solving, and performance in Electrical Technology Practical Assessment Tasks (PATs). Furthermore, this data was analyzed using descriptive and inferential statistics. Findings revealed that the majority of learners mostly relied on AI to complete written tasks and PATs, resulting in reduced critical thinking, limited conceptual understanding of electrical concepts, and poor practical performance. The study recommends the integration of digital ethics, guided AI use, and cognitive-based teaching strategies to foster independent reasoning and ensure learners acquire practical skills aligned with industry expectations.

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INTRODUCTION

In most recent years, the increasing dependence on artificial intelligence (AI) tools among learners in South African technical and vocational schools has started to reshape classroom learning dynamics, mostly in electrical technology. In the electrical technology curriculum, learners are expected to apply analytical reasoning to solve electrical problems and several technical issues revolving around the electrical field or context. However, that is still an unfulfilled dream, as many learners may depend on AI-created solutions for assignments, classwork, and even Practical Assessment Tasks (PATs), which brings an area of concern. The existing body of literature tends to assume that AI can assist learners to obtain high grades in school-based subjects, which may not be true in the context of teaching and learning a practical subject like electrical technology. This shift undermines the precise foundation of the electrical technology curriculum, which was designed to develop problem-solving skills, creativity, and technical expertise essential for producing competent artisans for the betterment of economic growth.

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In contrast, recent studies have shown that learners who use generative AI tools mostly improve their performance in assignments and in other tasks that are not completed under examination conditions (Cherki El Idrissi, 2025). While Wu and Yu (2024) argue that AI can help learners to improve their results, Challoumis (2024) presents a contrasting view highlighting that overreliance on AI hinders the development of practical reasoning and creative proficiency that underpins authentic skill acquisition and workplace readiness. Given that South African post-matric learners leave high school with few to no industry-related skills and competencies, this situation raises serious concerns about the declining engagement of electrical technology learners' cognitive abilities in settings where practical competence is necessary. Although ancient and recent studies have examined the implications of using AI to complete tasks, these studies have predominantly focused on higher institutions of learning while overlooking the contexts of high schools, which might have unique approaches to the utilization of AI. Hence, this study investigated how excessive reliance on AI affects learners' problem-solving skills and practical competence, which are vital for meeting the demands of the Electrical Technology curriculum and the broader technical industry.

This problem under investigation is particularly important for South Africa, where the shortage of skilled artisans continues to impede economic and industrial growth (Department of Higher Education and Training, 2022). When learners avoid critical thinking and depend more on technology tools like AI, such learners enter the workforce less equipped to diagnose electrical faults, interpret circuits, or apply theory in real contexts to solve arising problems. In support of this view, recent literature reveals that extreme technology dependence weakens learners' ability to transfer theoretical knowledge into real-world problem-solving, resulting in poor diagnostic and technical judgment (Aymen & Zakarya, 2024). Likewise, studies in vocational education contexts emphasize that authentic competence in technical subjects such as electrical technology is cultivated through persistent cognitive engagement and hands-on application, not through automated assistance (Huang, 2025). Addressing this problem is therefore not only an educational priority but also a national imperative for sustaining technical excellence and industrial productivity, thus bridging the gap between curriculum expectations and electrical technology classroom realities.

Furthermore, existing literature also highlights that AI, when integrated ethically and pedagogically, can support learning through adaptive feedback and simulation-based training (Dzhumatovich & Salimrouhi, 2025). Nevertheless, numerous studies warn that unregulated AI use fosters cognitive inactiveness, where learners reproduce information without understanding or reflection (Silva, 2024). In the South African context, few empirical studies have explored how this trend manifests in technical subjects requiring hands-on competence, like electrical technology, which brings an area of inquiry. Current studies tend to focus on higher education, overlooking a research gap on how AI dependence may compromise practical learning in vocational classrooms where independent reasoning remains a foundation of effective training. Hence, this study seeks to examine how excessive reliance on AI affects learners' problem-solving skills and practical competence, which are necessary for meeting the demands of the Electrical Technology curriculum and the broader technical industry as a whole.

The study contributes to the current body of existing knowledge by presenting local evidence of how AI dependency reduces the capacity of high school learners to think critically and apply knowledge practically to solve daily problems. Ideally, the findings of this study are expected to inform curriculum reform, emphasizing guided AI use, digital ethics for the use of AI tools, and pedagogical strategies that restore independent cognitive functioning in technical and vocational classrooms. By addressing this emerging challenge, the study aims to guide policymakers and teachers in designing interventions that balance technological innovation with reliable learning. Therefore, the purpose of this study is to explore how excessive reliance on AI affects learners' problem-solving skills and practical competence. Hence, this study was guided by the following research questions:

1. How does excessive reliance on AI affect learners' problem-solving skills in electrical technology classrooms?
2. In what ways does AI dependence influence learners' practical competence in electrical technology in South African technical schools?

RESEARCH METHOD

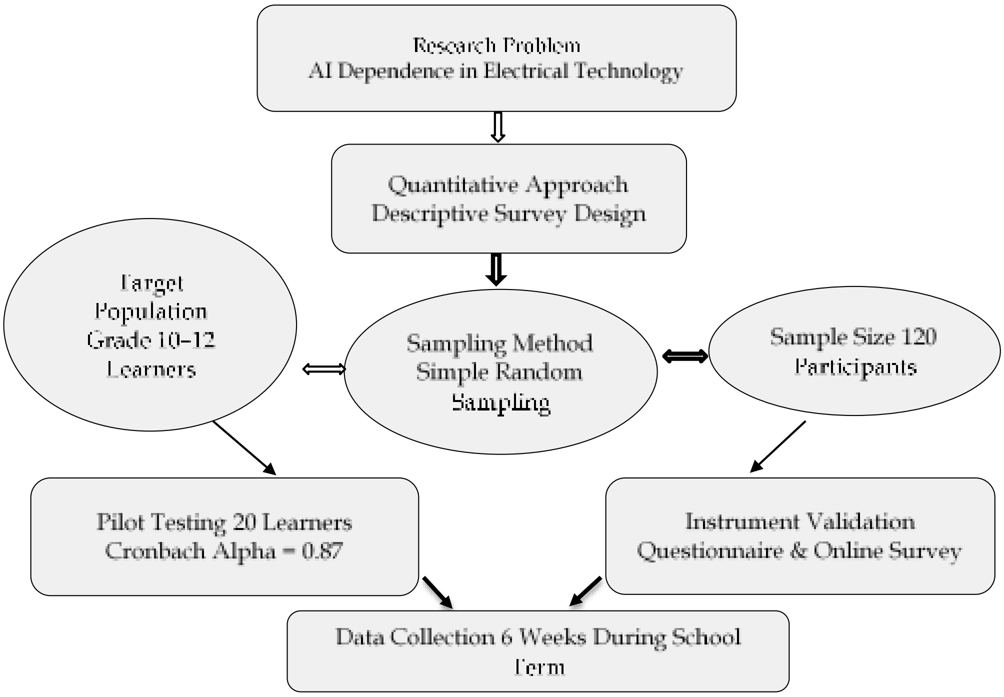

Figure 1: The research process flow-chat

As shown in Figure 1 above, this study used a quantitative research approach with a descriptive survey research design to explore how learners' dependence on artificial intelligence (AI) affects cognitive engagement and practical competence in electrical technology classrooms. According to Mohajan (2020), the quantitative research approach is a systematic method that focuses on collecting and analyzing numerical data to understand patterns, relationships, and trends. This research approach was selected because it enables the researcher to attain quantitative data from a larger sample while also forming links between the key research variables, which are AI use, cognitive engagement, and practical performance (Guo & Wang 2025). The target population for this study involved Grade 10 to 12 learners enrolled in Electrical Technology at four public technical high schools in Gauteng Province, South Africa. The sampled technical schools were selected because they represent a diversity of socioeconomic and learning environments common to South African technical and vocational schools. In order to guarantee that learners from different grades and schools were represented equally, a simple random sampling method was used to select participants of the current study. Hence, a total of 120 participants were selected from an estimated population of 400 learners. This sample size was regarded as sufficient to produce meaningful statistical inference while reducing sampling bias. The inclusion criteria of participants included only teachers who are teaching electrical technology in grades 10-12 and learners who are doing this subject in the very same grades or classes. In addition, only teachers with 3 or more years of experience teaching the subject in Further Education and Training (FET) who participated in this study are ensuring that their insights are arising from their long past experience about the subject. Furthermore, all teachers and learners who were not enrolled in electrical technology were excluded from this study, as they possess no relevant information pertaining to the subject.

The data was collected using two corresponding data collection instruments, a structured questionnaire and an online survey. The questionnaire included 33 closed-ended and Likert-scale questions designed to assess the frequency, purpose, and observed effects of using AI to complete electrical technology written and practical tasks like class work, quizzes, and practical assessment tasks (PATs) documents. In addition, these questionnaires also contained measures that assessed learners' problem-solving strategies and self-perceived confidence in doing practical electrical tasks. Furthermore, the online survey extended these findings by collecting more demographic information and learners' perspectives on how AI affects their conceptual understanding and skill development, among other aspects. These data collection instruments were derived from validated methods used in previous educational technology studies, and three topic experts scrutinized them for content validity.

The process of collecting data lasted six weeks, during the second school term of 2025. Questionnaires were distributed in person during planned electrical technology time slots in the school timetable, and online surveys were completed after school hours to minimize disturbance to teaching and learning time. In this study, participation was totally voluntary, and all ethical considerations, including informed consent, confidentiality, and anonymity, were carefully followed in accordance with ethical research norms established by the Gauteng provincial education department. Additionally, the data was analyzed using both descriptive and inferential statistical techniques. Descriptive statistics such as frequencies, averages, and percentages were used to summarize learners' AI usage habits and performance levels in PATs. Similarly, inferential statistics, such as Pearson correlation and regression analysis, were used to examine the links between AI dependency, cognitive engagement, and practical competence. Therefore, these investigations provided statistical proof of how AI use linked with learners' critical thinking and practical task performance.

To ensure reliability, a pilot test with 20 learners from a separate technical school was done prior to the main study. At this point, the pilot data was examined using Cronbach's alpha, which yielded a reliability coefficient of 0.87, suggesting strong internal consistency. Expert instrument review, conformity with the study's objectives, and triangulation of questionnaire and survey responses all contributed to increased validity. Prior to analysis of the collected data, statistical test assumptions such as normality and independence were tested to ensure that the findings were robust and reliable. While the study's scope is confined to four technical schools in Gauteng Province, this study offers an important understanding of AI's expanding influence on learning behavior in South African technical education. The findings are applicable to similar situations or contexts, while additional research including teachers from various provinces could provide greater insights. The methodology used in this study provided a clear and replicable framework for investigating AI-related learning problems in technical and vocational settings.

RESULTS AND DISCUSSION

This section provides and critically examines the findings on the usage of Artificial Intelligence (AI) by Electrical Technology learners, as well as the consequences for technical competence. The findings are organized to emphasize patterns of AI use, the relationship between dependence on AI and learners' performance in key skill domains, and the larger pedagogical implications for vocational education. The debate looks at how AI usage affects cognitive engagement, practical skill development, and alignment with curriculum objectives by combining quantitative evidence and qualitative perspectives.

Frequency of AI Usage Among Electrical Technology Learners

This study found significant trends in how learners interact with artificial intelligence (AI) tools while studying electrical technology in South African technical schools. Figure 1 demonstrates that 72% of respondents employed artificial intelligence (AI) platforms such as ChatGPT, Google Bard, and Quillbot to complete their assignments and practical assessment tasks. Only 18% recognized occasional use for clarification, and only 10% stated that they rarely or never used AI in their learning. This conclusion suggests a growing reliance on AI for problem-solving rather than the development of true technical and cognitive skills. Hernandez-de-Menendez, Escobar-Díaz, and Morales-Menendez (2020) discovered that students in vocational and engineering sectors prioritize creating tools for quick answers over analytical reasoning.

The findings of this study can further be understood through cognitive load theory, which explains that learners may choose automated systems when academic tasks are perceived as mentally demanding. In electrical technology, repeated dependence on AI-generated responses may reduce active mental processing required for circuit analysis and fault identification. Lestari, Winarsih, and Kusumawardani (2023) argue that meaningful learning occurs when learners actively process and organize information rather than receiving completed answers. In the current study, learners who frequently relied on AI demonstrated weaker engagement during practical activities and classroom discussions. This suggests that AI may gradually replace the mental effort required for technical reasoning.

These trends were supported by classroom observations and teacher interviews, which revealed learners typically duplicate AI-generated solutions without understanding the underlying electrical concepts. This behavior not only hinders learner problem-solving ability, but it also goes against the Curriculum and Assessment Policy Statement (CAPS) mandate for electrical technology, which encourages practical thinking and hands-on experience. According to Table 1, competence levels in fundamental areas such as circuit interpretation, problem diagnosis, and practical wiring have slipped below 50% among advanced AI users. This supports Levin, Marom, and Kojukhov's (2025) hypothesis that excessive dependence on generating tools might reduce learners' metacognitive engagement and hamper learning transfer to practical contexts.

The observed decline in practical competence also aligns with constructivist learning theory, which emphasizes that technical knowledge develops through active participation and experiential learning. Piaget's constructivist perspective maintains that learners build understanding through interaction with problems and practical experiences. In electrical technology classrooms, learners are expected to engage directly with electrical systems, interpret diagrams, and test solutions independently. However, the findings revealed that many learners bypassed these processes through AI-generated assistance. Similar observations were reported by Novikov and Kiseleva (2024), who found that overdependence on digital technologies weakens learners' independent knowledge construction in applied learning environments. Likewise, Khlaif, Alkouk, Salama, and Abu Eideh (2025) noted that generative AI systems may reduce deep learning when learners accept responses without reflection or verification.

The data discovered most learners relied significantly on artificial intelligence tools to complete academic and practical projects. Many learners used platforms like ChatGPT and Google Bard not as learning aids but as substitutes for cognitive engagement. This tendency corresponds to the issue raised by Hosseini, Horbach, Holmes, and Ross-Hellauer (2025), who discovered that a heavy reliance on generative tools substitutes critical thinking with automated responses. Similarly, Buddhadev (2025) noted that the growing tendency of AI dependency impairs learners' analytical abilities, particularly in skill-based disciplines. Such utilization has the potential to undermine the value of experience-based learning in South African technical colleges where electrical technology students are taught diagnostic and problem-solving abilities. The results highlight the significance of fostering appropriate AI use to preserve true learning and skill development. The figure below represents the frequency of AI usage among electrical technology learners.

The findings in Figure 2 clearly demonstrate that AI usage among electrical technology learners has progressed from a supporting learning tool to a reliance that undermines fundamental technical reasoning. This contradicts the curriculum's purpose of fostering the analytical and problem-solving skills required for trained artisans (DBE, 2021). Similarly, Mattsson, Fast-Berglund, and Thorvald (2020) argue that when learners minimize cognitive effort by automation, their aptitude for practical creativity suffers. In a comparable manner, Mishra, Gorakhnath, and Rani (2022) argue that effective technological integration should complement rather than replace educational ideas. As a result, the high frequency of AI reliance shows the vital necessity to steer learners toward balanced, pedagogically sound technology use, which is consistent with the study's purpose of ensuring that digital integration in electrical technology advances rather than undermines long-term skill development.

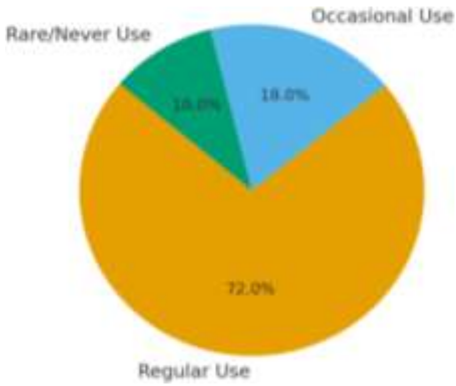

Figure 2. Frequency of AI usage among electrical technology learners

These findings are also consistent with recent studies conducted in technical and vocational education contexts. For example, Revesai (2025) reported that learners who depended heavily on generative AI showed reduced persistence when solving unfamiliar technical problems. In another study, Yavich (2025) found that AI-supported learning environments become problematic when learners use technology to avoid independent reasoning. Their study emphasized that unrestricted AI use may negatively influence self-regulated learning and technical confidence. Similarly, Jia and Tu (2022) observed that although AI can improve access to information, excessive use may weaken learners' motivation to engage deeply with subject content.

Within the South African context, the findings also reflect broader concerns regarding technical education and skills development. The Department of Higher Education and Training (2022) previously highlighted that many technical graduates enter industry with inadequate practical competence despite obtaining acceptable academic results. The present findings suggest that uncontrolled AI use may contribute to this challenge by limiting learners' opportunities to practice authentic problem-solving processes. This concern is important in electrical technology because practical competence depends on repeated cognitive engagement, procedural understanding, and physical application of technical principles.

In addition, the findings correspond with Vygotsky's social constructivist theory, which stresses the importance of guided learning and meaningful interaction during knowledge development. Although AI tools may provide academic support, they cannot fully replace teacher guidance, collaborative learning, and contextualized practical instruction. According to Luckin and Holmes (2021), educational technologies are most effective when they supplement rather than replace human cognitive processes. In the present study, learners who used AI mainly for clarification and revision demonstrated better classroom participation compared to those who depended entirely on automated responses. This indicates that balanced AI integration may still support learning when properly regulated within technical education settings.

The Relationship Between AI Dependence and Technical Expertise in Various Electrical Technology Skill Sets

The statistics in Table 1 demonstrate a significant difference between electrical technology learners who frequently use AI and those who do not. Learners who employed AI for classwork and Practical Assessment Tasks (PATs) performed much lower in critical areas like problem detection, circuit understanding, and theory application. This finding is consistent with Levin, Marom, and Kojukhov's (2025) warning that excessive automation in education lowers learners' metacognitive engagement and ability to apply knowledge in real-world circumstances. Similarly, Dayi, Mtshali, and Sephokgole (2026) discovered that in South African technical disciplines, important information is only gained when learners interact hands-on rather than reproducing computerized output. The evidence suggests that a strong reliance on AI not only degrades competency but also creates a gap between classroom accomplishment and industry preparedness. These results confirm the necessity of this study in addressing the imbalance between digital convenience and authentic skill development, as shown in Table 1 below.

Table 1. Skills competence and AI reliance

Skill Area	High AI Users (n=60)	Low AI Users (n=40)	Competence Gap (%)
Circuit Interpretation	44%	75%	31%
Fault Diagnosis	39%	78%	39%
Practical Wiring	47%	83%	36%
Application of Theory	41%	80%	39%
Safety Compliance	53%	85%	32%

The findings indicate a clear unfavourable relationship between excessive AI use and technical performance. Learners who used AI for classwork and projects had a lower ability to apply theoretical knowledge in real-world scenarios. These findings are consistent with Ghosh and Ravichandran's (2024) discovery that replacing exploration with automated digital feedback reduces true learning in technical courses. Similarly, White (2025) discovered that learners' excessive use of generating tools leads to "surface-level understanding", particularly in subjects that require hands-on reasoning and iterative problem-solving like electrical technology. Therefore, this study argues that, when AI is not used ethically, it reduces the learners' conceptual understanding of electrical technology and further weakens their practical competence in the electrical engineering field. Hence, the present study explored how cognitive skills in electrical technology are affected by AI dependence in South African technical schools.

As shown in Figure 2 below, learners who used AI less frequently had considerably higher competency scores across all electrical technology skill domains. This trend reinforces the idea that, while AI may be valuable as a complement, its unregulated use undermines the experiential and cognitive learning that is essential to professional training. According to Jain and Mitra (2025), technical education must strike a balance between digital literacy and physical handicraft, as the latter is essential for employability.

Comparison Between Competence and AI Reliance Across Skills

As illustrated in Figure 3 below, learners who used AI seldom displayed significantly higher ability in all practical and theoretical categories. Their performance in wiring, fault-finding, and theory application was better than that of frequent AI users, demonstrating that cognitive effort is still required to build technical abilities. This is consistent with Kovalchuk, Maslich, Tkachenko, Shevchuk, and Shchypska's (2022) claim that in vocational education, true proficiency is achieved by constant practice and guided reasoning rather than automated aid. Similarly, Peter, Gabraiel, and Johnson (2020) stated that cognitive apprenticeship, in which learners think over challenges, is essential for becoming artisans capable of making independent decisions. These data support the hypothesis that, when employed inappropriately, AI impairs the reflective learning process that is necessary for electrical technology education in South Africa. Hence, this study was significant in uncovering how technology, without ethical guidance, may unintentionally hinder skill acquisition.

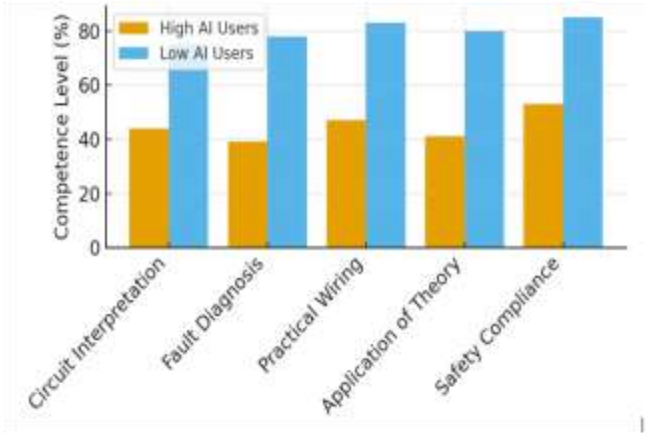

Figure 3. Comparison of competence and AI dependency across electrical technology skills

Teachers have observed that pupils have been increasingly failing to complete practical assessments without the use of AI technology, demonstrating a disconnect between digital fluency and technical reasoning. These findings support Burger and van Zyl's (2020) claim that South Africa's technical institutions should build cognitive apprenticeship models that scaffold learners' thinking before using automation. The study stresses the important necessity for well-defined norms that facilitate ethical AI integration while maintaining electrical technology's problem-solving capabilities. In conclusion, the data suggest that unmonitored AI use in technical classrooms affects learners' ability to reason independently and exhibit practical competence, resulting in consequences that clearly contradict the Electrical Technology curriculum's goals. This study contributes to the ongoing debates about the pedagogical ethics of AI in vocational education by emphasizing the importance of re-establishing human cognition, creativity, and problem-solving as critical pillars of technical and vocational learning.

CONCLUSION

This study reveals that electrical technology learners' overdependence on artificial intelligence (AI) significantly affects the development of critical technical and cognitive skills. The findings indicate that electrical technology learners in South African technical schools, particularly in Gauteng, are increasingly substituting AI-generated solutions for critical engagement and hands-on experience. This trend contradicts the intended results of the Electrical Technology curriculum, which emphasizes practical reasoning and experiential learning as the foundation for generating skilled artisans. These findings have a major significance, as they indicate a growing gap between curricular expectations and classroom realities in Gauteng's technical education system. While AI has the potential to improve access to knowledge, its unregulated usage risks reducing learners' preparation for industrial demands, where independent problem-solving and practical skills remain critical. This necessitates immediate, context-specific pedagogical solutions, such as clear policy guidelines for AI usage and specific teacher training and assessment changes that prioritize authentic, practice-based learning.

This study contributes to the ongoing discussion about digital transformation in vocational education by emphasizing the importance of establishing a balance between technology innovation and the maintenance of essential technical competencies. With that being said, future research should concentrate on building and testing sustainable AI integration frameworks specific to South African technical schools that offer electrical technology, particularly those in Gauteng province, to ensure that digital technologies supplement rather than replace meaningful learning and skill development in the subject. Furthermore, the findings of this study provide clear answers to the research questions by showing that excessive dependence on AI affects both learners' problem-solving skills and their practical competence in electrical technology classrooms. Many learners were found to rely on AI-generated responses when completing technical activities, instead of working through problems independently and applying their own reasoning. This reduced their engagement with important practical processes such as circuit interpretation, fault identification, and hands-on electrical tasks. The findings also revealed that learners who depended heavily on AI often experienced difficulties applying theoretical knowledge in real practical situations. Instead of using AI as a support tool, many learners appeared to use it as a replacement for active learning and critical thinking. As a result, opportunities for meaningful cognitive engagement were gradually reduced. These findings suggest that while AI can support learning when used responsibly, uncontrolled dependence on it may weaken the development of technical skills that are necessary in electrical technology and the broader technical industry. The study therefore concludes that AI should be carefully integrated into teaching and learning in ways that encourage independent thinking, practical participation, and deeper understanding of technical concepts.

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