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Concept paper: Efficiency of Artificial Intelligence (AI) tools For STEM Education In Malaysia

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Abstract

The concept paper identifies the relationship of Artificial Intelligence (AI) towards teaching and learning in STEM education. AI can really revolutionize STEM education if AI-powered tools are in place to ensure that each of the students receives personalized instructions, intelligent tutoring, and interactive simulations. Not only this, but they even grade assignments or quizzes that are submitted automatically and prove predictions with analytics to create efficiency and effectiveness in STEM pedagogy. However, there is a limited quantity of primary research regarding the actual impacts of such AI technologies. The paper will hence fill this gap by making an in-depth assessment of the application of AI tools in STEM classrooms. If strategically deployed, AI has huge potential to improve student mastery in STEM, increase learner motivation and autonomy, and allow teachers to become more personalized in their support. However, it also identifies challenges of equitable access, bias in algorithms, and wishing that the teachers have robust training programs. It thus proposes, based on the results, key recommendations that include developing ethical guidelines, investing in professional development, and designing AI systems accommodating diverse learning needs. To be precise, this research provides relevant empirical evidence and some practical guidance for education stakeholders to harness the transformative power of AI for STEM learning

Keywords: Artificial intelligence; STEM education; Teacher; Pedagogy; Teaching and learning

1. Introduction

STEM competencies are crucial for Malaysia's economic growth and advancement as a country. STEM skills are relevant not just to 'core STEM' jobs but also to many other careers in fact, Malaysia t targets to have 493,830 scientists and engineers by the year 2020 and become globally competitive. (Shahali, E. H. M., 2016) There is an acute shortage of engineers and professional STEM workers in Malaysia, which hinders economic growth and precipitates delays in projects, related cost escalation, and outsourcing of engineering tasks. Indeed, this supply issue is to be reduced at the very outset at the level of STEM education itself. STEM education gives rise to curiosity, inquisitiveness, critical thinking, and problem-solving skills, every one of them valuable for any STEM and non-STEM career. (Haston, A. L.,2020) This will help to bridge the gender gap because, as of now, women are less likely than men to graduate with STEM degrees. Encouraging girls in STEM right from their girl-child age is important for economic and social progress. One of the most important aspects of today's learning is STEM, its education that integrates the subjects of Science, Technology, Engineering, and Mathematics on how one is to think critically by solving problems and innovating. This has over the past few years received appreciable attention that integrating AI tools into STEM education is likely to enhance the learning experience and improve student outcomes.

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1.1. What is STEM Education?

STEM education is interdisciplinary in nature and focuses on the application of knowledge and acquisition of skills in the disciplines of science, technology, engineering, and mathematics, which will be applied in mechanisms of problem-solving. This will further enhance a hands-on, project-based learning environment and increase the understanding of the interrelationship of these fields with their real-life applications (International Conference of the Learning Sciences,2018). STEM education calls for students to form higher-order thinking skills and can implement what they are learning so that they create, evaluate, and analyze per Bloom's taxonomy.

1.2. What is Artificial-Intelligence (AI)?

Artificial intelligence is the part of computer science that develops systems and algorithms that perform tasks that are done by humans, such as decision making and problem solving. Artificial Intelligence has the potential to transform many areas in education, including STEM, by enabling personalization of learning experiences, intelligent tutoring systems, and adaptive learning environments. AI tools integrated into STEM education efficiently improve the process of learning, entailing individualized learning experiences for students through intelligent tutoring systems and adaptive learning environments. These tools can enable any student to learn at his or her pace, receive immediate feedback, and make use of resources tailored to his or her needs and preferences when it comes to learning. AI transforms and enhances most of the aspects of learning and teaching in STEM. Here is keyways AI is impacting STEM education:

1.3. Personalized Learning Experiences

AI algorithms can analyze student performance data to identify areas in which they need extra support and provide targeted, adaptive learning experiences that are tailored to each student's needs and pace. This makes it easier for students to learn efficiently and effectively. Kumar (2023)

1.4. Intelligent Tutoring Systems

Intelligent tutoring systems can provide extra support, much like a human tutor, to the conceptually challenged students enabling them to grasp concepts difficult for them. This would then enable pupils to stay at grade level for their class.

1.5. Adaptive Assessments

AI can provide students with personalized assessments that progress at their level, challenging them with questions that are neither too easy nor too hard. This builds student confidence and motivation while providing teachers with more accurate data on performance.

1.6. Virtual and Augmented Reality

AI empowers the creation of virtual and augmented reality interactive experiences that really help students engage better with, and understand, difficult STEM concepts. For example, through VR, they can walk through the human body or explore historical sites; through AR they will see mathematical concepts.

1.7. Automated Grading and Lesson Planning

AI can support teachers by auto-grading assignments and exams, saving time while providing uniform and accurate feedback. AI algorithms can also analyze student data to pinpoint exactly where they need the most extra help, providing teachers with ideas for targeted lessons. Kumar (2023). However, several other issues must be sorted out regarding integrating AI into STEM education, such as possible biases in AI algorithms, keeping a check on privacy, and training of teachers. Altogether, this relationship between STEM education and AI epitomizes a very promising outlook for AI in opening new opportunities to improve student learning and engagement at the initiation stage of STEM studies. While AI continues to further developments, its role in STEM education is only going to increase to prepare students for the future they will inherit, driven by AI.

1.8. Problem statement

- Evaluation of Effectiveness: On the effectiveness of AI-enabled STEM learning experiences, there is an exacting lack of full empirical studies to estimate the actual effectiveness of such learning experiences over traditional teaching techniques. Further rigorous studies should be informed to analyze the impact of AI on learner subject outcomes, learner engagement, and long-term knowledge retention in STEM fields.
- Deepening AI Methods for Adaptive and Inclusive STEM Education: Few studies have examined how more advanced AI techniques deep learning and natural language processing, especially can be combined with theories of learning to produce more efficient and inclusive learning experiences in STEM. It, therefore, opens

avenues for extending the application of AI in STEM education to further make it adaptive to a wide plethora of diversity in needs and backgrounds.

- Empower Teachers to Harness AI in STEM Classrooms: Most of the teaching population lacks the knowledge and resources for the proper use of AI as a teaching tool in the STEM classroom. Professional development programs need to be created that train teachers in both ways of integrating AI into instruction and issues of fairness, responsibility, and ethics in AI uses for STEM learning.

1.9. Research objective

Identify the Effectiveness of AI-Enabled STEM Learning Experiences: Conduct rigorous empirical studies to identify the impact of AI-enabled STEM learning experiences on student learning outcomes, engagement, and long-term knowledge retention, in comparison to traditional teaching methods.

Develop Advanced AI Techniques for Adaptive and Inclusive STEM Education: Identify how sophisticated AI methods like deep learning and natural language processing can be integrated with learning theories to create STEM learning experiences that are adaptive and inclusive to diverse student needs and backgrounds.

Identify ways of empowering teacher using the AI-Tools in STEM education.

2. Literature review

Within the past decade, artificial intelligence technologies have been incorporated into education at rapid speed as a promising way to improve teaching and learning outcomes in these critically needed fields of science, technology, engineering, and mathematics. (Idris, M.D.B.2018).AI can enable true individualization of learning experiences through which instructional strategies are to become more efficient and effective by offering real-time insights to students and teachers, especially in Malaysia where STEM education assumes a national importance, the efficiency and effectiveness of AI tools in enhancing STEM learning assume very importance. Several research studies have been conducted on the applications of AI in education. These AI-powered adaptive learning systems allow changes in content and pace based on the performance of each student, partially improving the learning outcomes. For example, Razzaq et al. (2005) demonstrated that students receiving mathematics through an AI-based tutoring system scored significantly higher in tests as compared to those taught by conventional instructional strategies. On the other hand, Nye et al. (2018) claimed that an AI-powered adaptive learning platform helped students achieve higher grades and lower failure rates within an introductory computer science course.

Beyond personalization, AI can further engage students and motivate their interest in STEM topics. It will be able to output interactive learning experiences that can make complex STEM topics more open to students through immersive technologies like virtual and augmented realties powered by AI. According to Ibáñez et al., in a study on the use of an AR-based learning system, the level of conceptual understanding and motivating learning in the electronics course had increased. A study conducted by Mohamad et al. in 2018 demonstrated that AI-driven educational gaming is very promising regarding enhancing STEM learning and its engagement among primary school students within the Malaysian context. Nevertheless, even as AI shows so much potential for STEM education, equally critical challenges and limitations must be sorted out. One critical concern in this area is the bias present within AI algorithms, which can bring about unfair or discriminatory effects if not properly designed and subsequently monitored for such issues. Further, the integration of AI into education brings certain highly relevant ethical concerns to the forefront, specifically regarding data privacy, transparency, and teachers' roles within an AI-augmented learning environment.

AI adoption in STEM education within Malaysia is at a very nascent stage, with extremely limited empirical studies on its effectiveness. For example, a study by Nordin et al. in 2016, examining Malaysian teachers' attitudes towards the integration of AI in education, reported that although the teachers are generally aware of the potentials and benefits of using AI, the number of means to train for and acquire resources on how to effectively teach through AI are few. A study carried out by Mohamad et al. in 2019 focused on the use of AI-powered chatbots for language learning in English at Malaysian secondary schools. The effects observed on student engagement and motivation were overall positive.

AI has further promise in STEM education through the growing recognition of individualized and adaptive approaches to learning. By way of adopting personalized learning that changes instruction based on the needs and preference of the student, it is probable to improve learning outcomes, particularly in areas of science, technology, engineering, and math by Amdan, M. A. B., Janius, N., Jasman, M. N. B., & Bin, M. A. H. (2024). By tapping into AI, adaptive learning systems can monitor data in real-time on students' performance, automatically changing the content, pacing, and instructional strategy for individual students with a view to attaining maximum learning outcomes.

Notably, in the Malaysian context, there is an acute need for personalized and adaptive STEM learning in view of the very diverse socio-economic and cultural backgrounds of students. According to Kamaruddin et al., 2019, it was found that Malaysian students from poor socioeconomic families, usually from rural areas, perform below average in the acquisition of science, technology, engineering, and mathematics due to insufficiency and a lack of resources and support. AI-enabled adaptive learning platforms can potentially close these gaps by providing individual support and intervention if something is going wrong with the student. Applications of AI in STEM education might be an innovative way to play out the strengthening of the teaching role and instructional practices in teachers. AI-powered tools can automate routine tasks, freeing up time for teachers from activities like grading and lesson planning to focus on more meaningful interactions with learners. Moreover, real-time insights about student performances are provided by AI-driven learning analytics to the teachers, by which teachers can identify the difficulty areas and work on their teaching strategies accordingly in this context, Zawacki-Richter et al. (2019). get Line However, there are several challenges to be addressed which will finally make AI embedding successful within the Malaysian STEM classroom setting. The first and most important is building the capacity and confidence of teachers in using AI technologies effectively. A study conducted in 2016 by Nordin et al. has revealed that, very few Malaysian teachers have received some training or are ready with the resources to integrate technology, let alone artificial intelligence, within pedagogical practice. Such a chasm will now need to be filled with thorough professional development programs purposed at empowering teachers to empower AI in the service of STEM education.

One more challenge is that implementation of AI in STEM education addresses the equity and inclusiveness concerns of Malaysian students' various needs and backgrounds. As Suresh and Guttag, 2019, raise if not designed and deployed with fairness and ethical considerations as integral priorities, AI algorithms could perpetuate biases and discrimination. thriving cooperation directly with educators, AI researchers, and the community stakeholders in the process of creating AI-empowered learning solutions within the gymnasium of STEM, which is accessible, inclusive, and responsive to the needs of all students. (Janius, N. ,2022)

In a nutshell, the literature suggests that AI has huge potential for improving STEM education in several ways through personalization of learning, increasing students' engagement, and deriving useful insights for teachers. In a bid to arrive at better understanding, further rigorous research is required with the efficiency and effectiveness of AI tools in Malaysian settings, especially regarding learning outcome enhancement, redressing equity and inclusion, and making teachers better placed at harnessing AI responsibly and effectively in their classrooms. It shall hence be seen that steps taken to deal with challenges in AI deployment and its limitations to STEM education will lead to an equitably distributed dividend of the technology toward overall improvement in STEM learning across Malaysia.

3. Expected outcomes of the studies

Table 1 Table of outcome (1.0)

Identify the Effectiveness of A.I. Enabled STEM Learning Experiences in Malaysia:
Establish through rigorous empirical studies whether and how AI-enabled STEM learning experiences work to bring about better student learning outcomes, enhance student engagement, and promote long-term knowledge retention in Malaysia, compared to traditional modes of teaching.
Determine how AI tools and technologies benefit or constrain STEM education within the Malaysian context.
Make evidence-based recommendations to optimize the integration of AI in Malaysian STEM classrooms for maximal efficacy.
To develop advanced AI techniques for adaptive and inclusive STEM education in Malaysia
Research how latest AI techniques, deep learning, and natural language processing can combine with theories of learning into the design of adaptive and responsive STEM learning experiences for diverse Malaysian learners.
Design and develop AI-driven, tailored STEM learning platforms that can individualize content, pace, or instructional strategies per student, depending on their performance and preference.
Examine how these more advanced, AI-powered STEM learning experiences may improve access, boost engagement, and drive further learning outcomes for currently underrepresented or disadvantaged groups of students within Malaysia.

4. Methodology

Table 2 Table of research methodology (2.0)

Research design	The study expected to be qualitative research design will include in-depth interviews with thematic data analysis. The qualitative approach has been chosen to gain deep understanding regarding what educators, students, and other stakeholders feel about AI tools in STEM education (user experiences, perceptions, and attitude).
Data collection	In depth interview with participants. Expected 10 participant from: STEM educator in all levels (primary, secondary and tertiary) Student enrolled in STEM education Educational Administrator 60 minutes – 90 minutes Interview session The interview will be recorded using audio recording
Data analysis	Thematic data analysis: Themes will be developed based on recurring patterns and significant insights related to the research questions.

4.1. Significance of the research

Integration of artificial intelligence into STEM can become a game-changing opportunity for improving learning outcomes and preparing the student for future technological advancement. The research aims to explore the efficiency of AI tools within Malaysian STEM classrooms, hence bridging an existing empirical literature gap on its overall impact. Knowing the effectiveness of AI in this context gives valuable insights to educators, policy makers, and stakeholders. Firstly, in finding a Challenges in Education, such resource constraints, variations of teacher expertise, and personalized learning experiences are many of the different challenges characterizing STEM education in Malaysia. Traditional teaching modes rarely consider these needs, which results in imbalanced student performance. AI tools shall be able to address these challenges through the provision of personal learning experience and intelligent tutoring systems to evaluate the adaptive characteristics of students. After that, Enhancing the teaching and learning using AI in STEM education. AI tools can really help drive change in STEM education, automate administrative tasks so teachers can focus on individualized instruction and mentorship. AI-powered platforms would aid teachers in grading, progress monitoring and reporting, and failure detection in students' knowledge to make it easier for them to formulate meaningful and targeted instructional strategies. In addition, innovative forms of teaching through virtual labs and interactive simulations will make complex concepts easier and more compelling to study. Besides, this integration of AI tools into STEM education is one significant move toward bringing educational equity. In Malaysia, there are differences in the extent of the educational resources and opportunities available both at urban and rural levels. AI tools can fill this gap with quality educating content and resources for students, regardless of their location. AI-powered learning platforms provide rich, dynamic, interactive experiences for students at remote locations, amounting to the reduction of inequalities in education. Furthermore, the Malaysian government strongly recognizes how STEM education contributes to economic growth and innovation. The Malaysian Education Blueprint 2013-2025 is one such initiative, focusing on improving STEM education for the surging demands of the workforce in the future. Application of AI tools in STEM education serves both steps at the national level by generating a technologically efficient and innovative generation. This study may enlighten the policymakers and can lead toward strategizing and developing policies for effective AI adoption in the education sector.

Moreover, the future workforce will be characterized by rapid technological advancement and a need to acquire skills in AI, Machine Learning, Data Science, and related areas of expertise in STEM. AI tools in STEM education can help position Malaysian students better in these growing job markets. Most AI tools allow practical projects, preferably learning concepts that incorporate the latest technologies at the highest possible level to enrich technical skills and digital literacy for employability. This contribution gives the enhancement needed for better employability and contributes to Malaysia's continuous economic growth with technological innovation. Then, AI could foster a culture of innovation and research within students and educators in STEM education. AI makes possible tools to realize collaborative learning and research projects utilizing students in real-world solving, innovation, and optimization. Educators could apply AI to pedagogical research, data analysis of student performance structures, and bringing about evidence-based teaching practices. This kind of continuous improvement will enhance STEM education and add new knowledge and technologies. In addition, AI can provide flexible and personalized learning opportunities throughout

an individual's life. Continuous learning and upskilling are necessary for survival in the job market due to the rapidly changing world with respect to technological advancement. AI-powered learning platforms can offer learners a personalized pathway of learning including adaptive content and real-time feedback. This allows a learner who wants to gain new skills and knowledge to acquire them at any time in their lives. This would foster a workforce of skilled, adaptable labor that will meet evolving economic demands in a better way. Then, his study has a host of implications for the EdTech industry in Malaysia. The identification of the AI tools that are most effective in impacting STEM education will help in guiding the development or improvement of offered EdTech products and services. It will harness EdTech players for deep insights into the development of innovative, AI-driven solutions for the Malaysian educational system, atop specific needs and challenges. This can engender an EdTech sector and new business opportunities. Lastly, while this study was conducted in Malaysia, it can draw further implications for other countries that are currently facing related challenges in STEM education. Informed by the insights of this study, best practices at the global level on the integration of AI in education would also benefit from it, therefore feeding into the debate at the international level. The sharing of knowledge and experiences among countries enables learning from each other and collaborative strategy development to enhance STEM through AI. This study, foreseen to empower STEM education in Malaysia with AI tools. The importance of the study can also be affirmed by its impact on resolving educational challenges, promoting equity, adhering to national policies, preparing students for the future workforce, supporting innovation, enabling lifelong learning, and finally providing information to the EdTech industry. It's expected to help in the development of effective AI-driven educational strategies and policies toward enhancing the quality of STEM education in Malaysia and remaining competitive in the global knowledge economy.

5. Conclusion

In conclusion the promise of AI tools in the integration with STEM education in Malaysia is very bright, with an improvement in learning outcomes, promotion of educational equity, and preparing students for technological innovation. Therefore, Malaysia can explore the transformative potentials of AI to improve the quality of STEM education by addressing these challenges and with monetary investment in professional development, further research in this area and ethical deployment of AI. The paper provides some useful insights and practical recommendations for educators, policymakers, and stakeholders to ensure the fullest possible utilization of AI for STEM education in promoting economic growth and innovation for the nation. The results are relevant not only at the national level for Malaysia but also for other countries that struggling with similar challenges in STEM education-related issues.

Compliance with ethical standards

Acknowledgement

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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