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Impact of AI in teaching and learning of CS in low-resourced schools.

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Abstract

This research investigates the impact of Artificial Intelligence (AI) on the teaching and learning of Computer Science (CS) in low-resourced schools. The study aims to understand how AI is currently being utilized in CS education, assess the benefits it offers, and identify the challenges faced by low-resourced schools in implementing these technologies. Two primary methods were employed: an interview with the founder of Rehan School, a low-resourced school utilizing AI tools like ChatGPT and virtual assistants, and a comparative study analyzing students' performance from low-resourced and well-resourced schools using different learning resources.

Key findings reveal that AI technologies significantly enhance student engagement and learning outcomes in CS education by providing personalized learning experiences and access to advanced educational resources. However, limited infrastructure, funding, and staff training remain significant barriers to widespread adoption. The study concludes that while AI has the potential to bridge educational gaps in low-resourced settings, addressing these challenges is crucial for maximizing its benefits. The findings suggest a need for targeted policies and investments to support the integration of AI in education, particularly in underfunded schools.

Keyword: AI; CS; Low-resourced schools; Student

1. Introduction

Artificial Intelligence (AI) is revolutionizing various sectors, including education, by offering innovative solutions to enhance teaching and learning experiences. In Computer Science (CS) education, AI technologies such as adaptive learning systems, intelligent tutoring, and virtual assistants are transforming traditional pedagogical

methods. This transformation is particularly significant in low-resourced schools, where access to quality educational materials and specialized instructors is often limited. By leveraging AI, these schools can provide personalized and interactive learning experiences, potentially leveling the playing field for students who otherwise face educational disparities.

This study explores the impact of AI on the teaching and learning of CS in low-resourced schools, addressing the following research questions:

- How is AI currently being used in CS education?
- What are the benefits of AI in CS education in low-resourced schools?
- What challenges do low-resourced schools face in implementing AI?

These questions guide the investigation into the current applications, benefits, and challenges of integrating AI in CS education, providing a comprehensive overview of its potential and limitations in these settings.

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2. Literature review

With the advancement of artificial intelligence (AI) and computational technologies, the educational landscape, particularly in Computer Science (CS), has been significantly transformed. The integration of AI in education (AIEd) offers new ways to enhance both teaching and learning processes, especially in low-resourced schools where access to quality education and materials is often limited (1,4,6). This review synthesizes recent findings on the application of AI in CS education, focusing on its impact in underfunded and resource-constrained settings.

2.1. Enhancing Instructional Design and Pedagogical Approaches

AI technologies are revolutionizing instructional design by providing tools for automatic assessment, personalized learning experiences, and adaptive feedback systems. These tools enable educators to monitor and evaluate student performance in real time, thereby allowing for immediate interventions to address learning gaps (1,10,12). For example, AI systems have been effectively used to enhance blended learning environments by integrating AI-driven analysis and support into traditional classroom settings, thus providing a more tailored educational experience (3,8).

2.2. Supporting Student-Centered Learning

One of the most significant advantages of AI in CS education is its ability to support student-centered learning through adaptive tutoring systems and personalized learning resources. These systems use data analytics and machine learning algorithms to adjust the difficulty level and content based on individual student needs, thereby enhancing engagement and learning outcomes (7,11). This personalized approach is particularly beneficial in low-resourced schools, where there may be a shortage of specialized instructors and educational resources (15,17).

2.3. Challenges and Considerations in Low-Resourced Settings

While the potential benefits of AI in education are substantial, several challenges must be addressed to effectively implement these technologies in low-resourced schools. Key issues include limited infrastructure, insufficient funding, and a lack of trained personnel to manage and operate AI systems (14,16). Additionally, the success of AI applications in education is contingent upon the contextualization of resources and curricula to suit the specific needs of the school environment and student demographics (13,15). There is a critical need for policies and strategies that consider these socio-economic factors to ensure equitable access to AI-enhanced education.

2.4. Broader Impacts and Future Directions

The integration of AI in CS education also raises broader questions about the role of technology in the classroom and its impact on the instructor-student relationship. Studies have shown that AI can serve as both a supplementary tool for teachers and a primary medium of instruction, depending on the educational context (9,18). As AI continues to evolve, there is a growing need for research on its long-term impacts, particularly concerning educational equity and the digital divide (2,17).

3. Methodology

Interview with Mr. Rehan Allahwala, Founder of Rehan School

3.1. Participant and Context

The interview was conducted with Mr. Rehan Allahwala, the founder of Rehan School, a low-resource educational institution located in Korangi, a socio-economically challenged area in Karachi, Pakistan. The school is notable for its innovative use of AI technologies to enhance the learning experience, particularly in Computer Science (CS) education.

3.2. Data Collection Process

The interview followed a semi-structured format, allowing for both guided questions and open-ended responses. This methodology facilitated a comprehensive exploration of the school's educational practices and the challenges associated with implementing AI technologies.

3.3. Key Findings

Integration of AI Technologies: Rehan School employs various AI tools, including Alexa, ChatGPT, Google Assistant, and other AI applications, to teach students critical CS skills such as coding, prompt engineering, software development, and

web development. Mr. Rehan emphasized that these technologies not only provide students with technical skills but also promote an ethical approach to technology use.

Role of AI in Education: AI tools serve as supplementary educational resources at Rehan School, enhancing rather than replacing traditional teaching roles. For example, ChatGPT allows students to interact with AI in a way that simulates personalized tutoring, making complex concepts more accessible. This approach aligns with the school's objective to foster deep conceptual understanding rather than rote memorization.

Use of GPT Technology: A standout feature of Rehan School's curriculum is the use of GPT (Generative Pre-trained Transformer) technology, specifically designed to teach O-Level Computer Science. The school has developed a specialized GPT model, named "Rehan School O-Level Teacher," which is accessible to students worldwide. This tool provides tailored explanations and exercises, helping students understand and apply key concepts in computer science.

Technological Resources and Student Engagement: Each student is equipped with a laptop and a mobile phone, valued at PKR 10,000 and PKR 8,000, respectively. This investment ensures that students have the necessary tools to engage with AI technologies effectively. Teachers at Rehan School have observed that AI integration has reduced their workload by enabling students to independently explore and resolve programming and CS queries.

Innovative Learning Environments: Rehan School has established specialized environments, such as the "AI" and "Future Navigator" rooms, designed to foster creativity and focus. These spaces encourage students to apply their skills in practical projects, such as small software and game development, which are considered essential for future career readiness.

Challenges and Community Response: The school faced resistance from some parents who were skeptical of the AI-driven learning approach, viewing it as a potential distraction or a waste of time. Despite these challenges, Mr. Rehan remains a strong advocate for this modern educational method, arguing that traditional models focused on scores and rote learning are inadequate for preparing students for future technological landscapes.

Vision for the Future: Mr. Rehan envisions a future where AI is an integral component of education. He emphasizes the importance of students mastering prompt engineering and other AI-related skills to remain competitive. He also calls for government initiatives to provide technological resources, such as laptops and mobile phones, to students in low-resource areas, either through subsidies or free distribution, to ensure equitable access to modern education.

Comparative Study: Impact of AI on Student Performance in Computer Science

3.3.1. Objective

The study aimed to assess the impact of AI tools on the learning outcomes of students from low-resourced and well-resourced schools in Karachi, focusing on Computer Science (CS) topics such as data representation and Visual Basic programming basics.

3.4. Participants

- Student A: An average student from Govt. Dehli Boys School, a low-resourced school.
- Student B: A top-ranking student from City School, a well-resourced private school.

3.4.1. Materials and Resources

- Student A: Provided with a basic course book and access to ChatGPT for learning and clarifications.
- Student B: Provided with a comprehensive course book, teacher's notes, and revision materials from the online platform Z-Notes.

3.5. Procedure

3.5.1. Preparation Phase

Both students were asked to prepare for a test covering data representation (binary and hexadecimal conversions) and Visual Basic coding basics (loops, conditionals, and declarations).

- Student A utilized ChatGPT to plan and study, using the course book minimally to identify key areas.
- Student B relied solely on traditional resources such as books, class notes, and Z-Notes.

3.5.2. Test Design

The test included two questions worth 20 marks:

- A theoretical question on the importance of binary data representation in computers and a practical task to convert hexadecimal to binary.
- A programming task to write a Visual Basic program for sorting an array in ascending order.

3.5.3. Assessment and Analysis

The students' answers were evaluated based on accuracy, comprehensiveness, and code efficiency.

An additional assessment was conducted to gauge the students' understanding and critical thinking by discussing their answers written in their test and identifying any rote memorization.

4. Results

4.1. Method 1: Case Study of Rehan School

4.1.1. AI Integration and Learning Enhancement

The interview with Mr. Rehan Allahwala, the founder of Rehan School, highlighted the integration of AI technologies in a low-resourced educational environment. The school utilizes AI tools like Alexa, ChatGPT, and Google Assistant to teach students essential skills in Computer Science, including coding, prompt engineering, software development, and web development. These tools are not used to replace teachers but rather to complement and enhance their teaching. The students leverage these technologies to gain a deeper understanding of the subjects, facilitated by interactive and personalized learning experiences.

4.1.2. Student Engagement and Performance

Students at Rehan School engage actively with AI tools, which has resulted in a noticeable improvement in their comprehension and problem-solving abilities. The use of ChatGPT, in particular, has allowed students to explore complex concepts and obtain instant clarifications. This has led to more detailed and informed responses in their work, as well as the development of practical skills that go beyond the traditional curriculum. The school's initiative to create AI-powered tools like the Rehan School O-Level Teacher demonstrates their commitment to making advanced learning accessible to a wider audience.

4.1.3. Challenges and Future Directions

Despite the successes, the school faces challenges, particularly in gaining acceptance from parents who are skeptical of AI-based learning methods. Mr. Rehan emphasized the need for government support in providing resources like laptops and mobile devices to students in low-resource areas, which would further enhance the learning experience and prepare students for future technological advancements.

4.2. Method 2: Comparative Study of Student Performance

4.2.1. Test Results:

Performance Scores:

- The well-resourced school student scored 17 out of 20 marks.
- The low-resourced school student scored 19 out of 20 marks.
- Quality of Responses and Coding Skills

The well-resourced school student's responses were concise but limited to the information provided in their study materials. The code produced was functional but lacked efficiency. When asked to explain the concepts behind their answers, the student could not provide insights beyond what was covered in the course material, indicating a reliance on rote memorization rather than critical thinking.

In contrast, the low-resourced school student's responses were more comprehensive, demonstrating a deeper understanding of the material. The student exhibited advanced coding skills, employing efficient techniques that are not

typically covered in high school curricula. When asked about the concepts behind their answers, the student provided detailed explanations and even shared insights beyond the textbook, such as explaining that binary representation is like the on-off states of a machine and a logical way by which machines communicate. In comparison, the well-resourced school student's response to the same question was limited to stating that "the binary number system is a base 2 number system." The depth of understanding shown by the low-resourced school student was attributed to the interactive and informative guidance provided by ChatGPT.

This is the Graph that represents the rating for the Answers of both students:

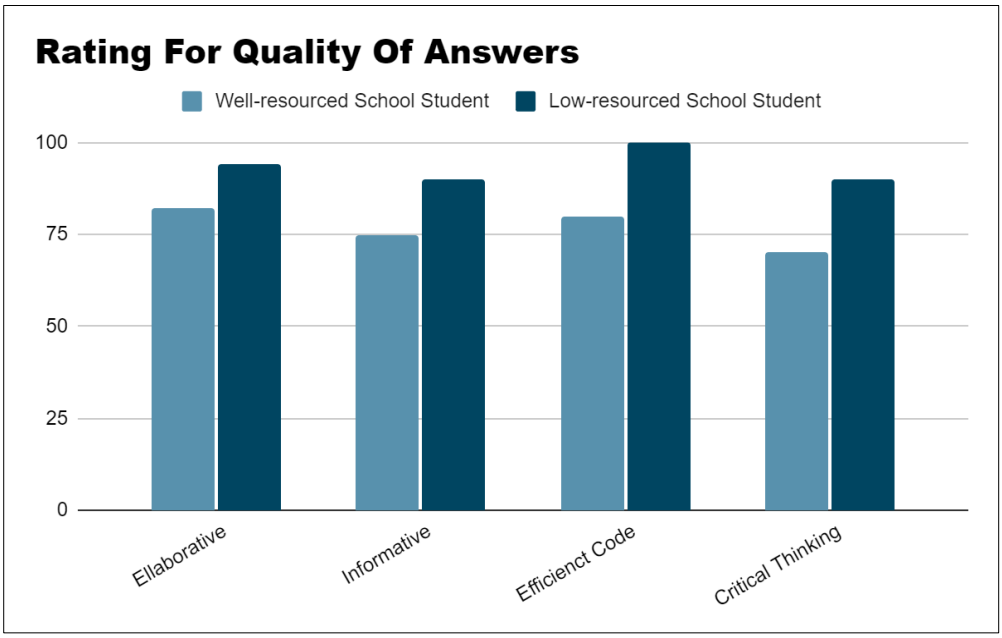

Figure 1 Comparison of Answer Quality between Well-Resourced and Low-Resourced Students

5. Discussion

5.1. Interpretation of the Findings

The findings from this study highlight the transformative potential of AI in enhancing Computer Science (CS) education in low-resourced schools. The case study of Rehan School and the comparative study between students from low- and well-resourced schools demonstrate that AI tools such as ChatGPT and other virtual assistants can significantly enhance students' understanding and performance in CS subjects. The use of AI not only facilitates personalized learning but also helps in developing critical thinking and problem-solving skills, as seen in the more detailed and efficient responses from the low-resourced school student.

5.2. Implications for Teaching and Learning in Low-Resource Schools

The integration of AI in education can serve as a powerful equalizer, providing students in low-resource schools with access to high-quality educational content and personalized learning experiences that would otherwise be unavailable. The ability of AI to adapt to individual learning needs and provide instant feedback helps bridge the gap caused by the lack of specialized teachers and educational materials. This approach not only enhances academic performance but also prepares students for future technological advancements, equipping them with essential skills such as coding, prompt engineering, and software development.

5.3. Comparison with Existing Literature

The findings of this study align with the existing literature on the benefits of AI in education, particularly in low-resource settings. Previous research has shown that AI can revolutionize instructional design and support student-centered learning by offering personalized and adaptive educational experiences (1,5). This study further substantiates these claims by demonstrating tangible improvements in student performance and engagement when AI tools are integrated

into the learning process. However, it also highlights unique challenges specific to low-resource environments, such as infrastructure limitations and the need for contextualized curricula (14).

5.4. Limitations of the Study

This study has several limitations that should be considered when interpreting the findings. Firstly, the sample size was limited, with data collected from only one school and a comparative study of two students, which may not fully represent the broader educational landscape. Secondly, the study relied heavily on qualitative data from interviews and student performances, which may introduce subjectivity. Finally, the comparative study focused on a specific set of skills in CS, and the findings may not be generalizable to other subjects or grade levels.

5.5. Recommendations for Future Research

Future research should focus on expanding the sample size to include a more diverse range of schools and students to better understand the impact of AI on different educational contexts. Longitudinal studies would be beneficial in assessing the long-term effects of AI on student learning outcomes, teacher roles, and educational equity. Additionally, research should explore the development of cost-effective AI tools specifically designed for low-resourced schools, addressing unique challenges such as limited infrastructure and funding. Finally, there is a need for policy-oriented studies to formulate strategies that can support the widespread implementation of AI in education, ensuring that the benefits of this technology are accessible to all students, regardless of their socio-economic background.

6. Conclusion

6.1. Summary of Key Findings

This study aimed to answer three primary research questions concerning the impact of AI on Computer Science (CS) education in low-resourced schools. The findings reveal that AI is being utilized in various innovative ways, such as using AI-powered tools like ChatGPT, virtual assistants, and other educational software to teach coding, prompt engineering, and other CS skills. These tools are integrated into the curriculum to enhance students' learning experiences, provide personalized feedback, and support educators in delivering complex content.

6.2. Overall Conclusions Drawn from the Study

The benefits of AI in CS education, particularly in low-resourced schools, are significant. AI technologies offer personalized and adaptive learning experiences that cater to individual student needs, thereby improving engagement and learning outcomes. The case of Rehan School and the comparative study between students from different socio-economic backgrounds demonstrated that AI could help bridge the educational gap, allowing students from low-resourced schools to achieve comparable, if not superior, academic outcomes compared to their peers in well-resourced schools.

However, the implementation of AI in low-resourced schools is not without challenges. Key issues include limited access to technology, insufficient funding for infrastructure and devices, and a lack of trained educators to effectively integrate AI into the teaching process. These challenges highlight the need for targeted policies and support to enable the broader adoption of AI in education, ensuring that all students can benefit from these technological advancements.

6.3. Final Thoughts on the Impact of AI on Education in Low-Resource Settings

The study underscores the transformative potential of AI in education, particularly in providing high-quality learning experiences in low-resource settings. While AI has shown promise in enhancing CS education by making it more accessible and engaging, significant barriers remain that must be addressed to realize its full potential. As AI continues to evolve, it is crucial for stakeholders, including policymakers, educators, and technology developers, to collaborate in developing strategies that overcome these challenges and promote equitable access to AI-enhanced education. This will not only improve educational outcomes but also help prepare students for the demands of a technology-driven future, fostering a more inclusive and skilled workforce.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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