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Impact of AI-Based Teaching Techniques on Learning Outcomes of Primary School Children: A Quantitative Study

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ABSTRACT

The growing popularity of the application of Artificial Intelligence (AI) to the education environment has transformed the practice of teaching and learning, especially in terms of customization, flexibility, and data-based learning. The given quantitative research designates the effect of AI-based instructional approaches on the academic achievements of primary schoolers. The data were gathered with the help of a pre-test and post-test research design and were obtained among primary school students who were exposed to AI-based instructional tools, i.e., adaptive learning platforms and intelligent tutoring systems. The difference in academic performance and level of engagement was measured prior to and after the intervention using statistical analysis. The results demonstrate that AI-based instructional strategies can positively impact the learning performance of students statistically significantly, improving academic performance and engagement of the learners in contrast to conventional teaching practices. The paper is an important contribution on the pedagogical importance of AI in primary education, and it is supported by empirical evidence that can be used to make informed judgments about the use of technology during early educational activities.

Keywords: *Artificial Intelligence in education; artificial intelligence teaching; primary school children; learning outcomes; quantitative study.*

INTRODUCTION

The world is facing a fundamental change in the education systems as technological change is taking place at a very high pace. One of such developments is the emergence of Artificial Intelligence (AI) that can be used as a potent instrument that can redefine the instruction process and learning experience. AI means computer systems which are selected to address tasks that are traditionally performed by human intelligence like problem-solving, pattern recognition, and decision-making (Russell & Norvig, 2021). Education AI is finding more applications in the teaching process, such as smart tutoring systems, adaptive learning programs, automated assessment and grading systems and customized comments.

The increased use of AI in education is conditioned by the desire to deal with the same problems in the traditional classroom, such as a large number of students in the classroom, the diversity of student needs, and insufficient attention to each student. Traditional methods of teaching usually depend on standardized learning and this might not be able to cater to varying cognitive ability, learning style, and background in learners. This is where AI-related teaching methods can be used to address these shortcomings and provide information and individual-centered learning that readjusts to performance on the spot (Holmes et al., 2021).

Primary education is a basic phase in the academic and cognitive growth of the child. In this stage, the learners will gain the necessary skills in literacy, numeracy and problem solving which will determine their future success in their education. The implementation of AI-based pedagogical methods at this stage has

acquired growing popularity, because initial exposure to adaptive and interactive learning culture could lead to improvement in motivation, understanding, and memory (Zawacki-Richter et al., 2019).

Teaching methods based on AI within primary schools are often adaptive learning platforms that change the content difficulty, intelligent tutoring systems, which step-by-step guide the learner, and gamified applications, which rely on AI algorithms to keep the learner engaged. The tools work based on the analysis of the answers provided by the students, the detection of learning gaps, and the provision of the students with the individualized instructional material. These methods are consistent with child-centered pedagogies which focus on active learning, immediate feedback, and constant evaluation (Luckin et al., 2016).

The outcomes of learning are considered to be one of the main indicators of the effectiveness of education. They also describe quantifiable variations in knowledge, skills, attitudes and competencies which are accomplished through instructional activities (Biggs and Tang, 2011). As part of primary education, learning outcomes are normally evaluated in the form of academic achievement scores, acquisition of skills, as well as levels of engagement. At this age, it is paramount to enhance learning outcomes, and the academic achievement at an early age has a strong correlation with educational achievement in the long run and socio-emotional maturity (OECD, 2019).

The AI-based instruction methods are aimed at improving the learning outcomes through facilitating personalized instruction and minimizing cognitive load. The AI systems will be able to deliver prompt feedback and specific interventions through continuous monitoring of the progress of a particular learner, thus facilitating the mastery learning process. The studies indicate that the individualized learning conditions are able to achieve large gains in academic performance and learner motivation, especially in young students who gain advantages of interactive and visually rich content (Pane et al., 2017).

Constructivist and social constructivist learning theories provide the theoretical foundation of the use of AI in educational activities. According to Piaget (1952), the constructivist theory assembles that learners are active in the process of building knowledge by interacting with their surrounding environment. Tools based on artificial intelligence can facilitate the process as they allow learners to explore, learn through practice, and learn at their own pace. Learners are not inert receivers of information but participants in the process of knowledge construction.

On the same note, the idea of the Zone of Proximal Development by Vygotsky (1978) emphasizes the significance of guided learning and scaffolding. Teaching methods based on AI are digital scaffolds and provide hints, prompts, as well as feedback that are at the level of development of learners. The AI-based tools assist in overcoming the difference between what learners can and could do on their own without assistance and what they can do with help, therefore, allow learning at a deeper level.

Current empirical studies have demonstrated that AI-based teaching can have a positive impact on the learning outcomes on different educational levels. Research in the context of both secondary and higher education has shown that the use of AI-based tools in the instructional process has led to positive changes in the academic results, development of problem-solving abilities, and the interest of the learner (Chen et al., 2020; Kulik and Fletcher, 2016). Nevertheless, the literature on primary school children is still rather sparse.

Though certain researchers are of the view that adaptive and interactive learning environment are beneficial to the younger learners, others advocate empirical validation of this using quantitative research. The success of AI-based instructional methods can be different according to age, subject matter, and design. Thus, a quantitative study should be conducted systematically to address the question of whether AI-defined methods of teaching can lead to quantifiable changes in the learning outcomes of primary school students.

Although the use of AI in primary education is growing, the existence of strong quantitative data evaluating the effects of AI on the learning outcomes in primary school level is rather scarce. A lot of the literature available is either conceptual or is dealing with older learners and thus there is a major gap in empirical studies of primary school populations. Moreover, qualitative observations are used in many studies instead of statistical analysis, which restricts the applicability of the results.

This gap needs to be filled by educators, school administrators, and policymakers who want to be provided with evidence-based information on how to incorporate AI into primary classes. The knowledge of how much AI-based pedagogical tools can affect the learning outcomes can be used to inform the development of the curriculum, teacher education, and educational technology policies. Quantitative approach is objective in measurement and comparisons and thus enhances validity of the conclusions made out of the study.

The current research aims at quantitative research on the effects of AI-based pedagogy on the academic performance of primary school students. Through the use of pre-test and post-test data, the study would offer empirical data on the effectiveness of AI-supported instruction to increase academic performance and engagement. The research paper adds to the current literature on educational technology since it pays attention to early education and learning outcomes.

Research Objectives

1. To estimate how AI-based teaching methods affect the learning performance of primary school children.

2. To examine the connection between AI-based methods of teaching and the achievement of students at the primary school level.

Research Questions

1. How will AI-based teaching methods affect the learning outcomes among primary school children?

2. Does using AI-based teaching methods and academic performance at the primary school level have a significant relationship?

LITERATURE REVIEW

One of the most powerful technological changes that has developed in the sphere of contemporary education is Artificial Intelligence (AI). AI describes computer-based systems that are able to execute what humans normally do using their intelligence, including learning, reasoning, problem-solving, and decision-making (Russell and Norvig, 2021). In the educational setting, AI is being increasingly used to improve the process of instruction, personalized learning, and assessment. The attraction towards the AI-driven methods of teaching is explained by the necessity to resolve the long-standing issues in the conventional classroom, such as variations in learning capacities of the learners, lack of teaching time, and the absence of personalized feedback. Consequently, scientists and educators have started to consider AI as a way of enhancing learning processes and educational results on the various education levels.

The AI-based instructional methods include various applications aimed at facilitating the teaching and learning experiences by automating, adapting and analyzing data. The techniques are intelligent tutoring systems, adaptive learning systems, AI-based educational games, automated feedback systems, and learning analytics. These systems work on the principle of gathering real-time information about the performance

and behavior of learners helping to adjust instructional content to the needs of individuals (Luckin et al., 2016). One of the benefits of AI-based teaching was found to be personalized instruction, through which learners are able to learn at their own pace and get specific assistance. Research indicates that personalization leads to better motivation of learners, increased understanding, and positive academic performance (Holmes et al., 2021).

It is especially important that AI-based instructional methods are applied in the primary education, where students are at the early stages of cognitive and academic growth. The learning styles, attention span and skill acquisition rates of primary school children are varied and this aspect renders uniformity in instruction methods ineffective. Tools supported by the AIs provide interactive and graphic learning experiences that can be offered in accordance with the developmental requirements of children. The adaptive reading application, such as one, helps learners develop their literacy with their feedback modulating the level of difficulty, and AI-based mathematics applications offer step-by-step advice on the learners to enhance their numeracy skills (Pane et al., 2017). These are the tools that are aimed at active participation and continuous attention and are vital in effective learning in the primary level.

Primary education learning outcomes are usually stated as quantifiable alterations in the knowledge of students, their skills, attitudes, and behaviors as the results of the instructional manipulations (Biggs and Tang, 2011). The most common indicators of learning outcomes include academic achievement, mastery of skills and involvement of learners. The enhancement of learning results on the primary level is essential because the academic achievement at this stage is closely linked with the subsequent education levels and the ability to learn throughout the lifetime (OECD, 2019). The goals of using AI-based instructions in teaching practice include improving learning experience as it offers continuous evaluation and immediate feedback as well as offers personalized practice opportunities. This is because by detecting the learning gaps at the earlier stages, AI systems allow timely intervention hence decreasing chances of failure in academics.

Theories AI-based teaching methods are based on constructivist and social constructivist theories of learning. The constructivist theory begs to differ by highlighting that learners actively build the knowledge they have by engaging with their environment and not passively taking in the information (Piaget, 1952). Learning environments that are based on AI assist in this process by promoting exploration, practice, and problem-solving. Students are exposed to adjusted material, they get immediate feedback, and they polish their knowledge through repetition. The social constructivist theory also brings up the importance of guided support and scaffolding in learning, as well as through the concept of the Zone of Proximal Development introduced by Vygotsky (Vygotsky, 1978). AI-based systems deliver hints, cues, and progressive challenges which are relevant to the existing capabilities of learners and, through this method, enable them to attain cognitive growth over time as scaffolds.

The effectiveness of AI-based teaching techniques has been actively investigated by empirical studies to enhance the outcomes of learning activities. In the meta-analysis of intelligent tutoring systems, Kulik and Fletcher (2016) demonstrated that there were significant learning advantages in comparison to the classroom teaching. Their results indicate that AI-assisted teaching may result in increased levels of achievement because of the personal feedback and progression based on the mastery. Likewise, Chen et al. (2020) discovered that AI-based educational interventions have a positive impact on academic performance, engagement of learners, and their satisfaction. These researches give a good argument in favor of the power of AI in improving the process of learning.

According to the studies in the area of primary school, it has been revealed that AI-driven methods of teaching may result in the quantifiable gains to the academic performance, especially in mathematics and language acquisition. Learning platforms based on adaptive learning were proved to be efficient with

problem solving abilities because learners can train at their correct levels, whereas AI-assisted reading tools develop vocabularies and understanding (Pane et al., 2017). In addition, gamified artificially intelligent programs can help improve the level of motivation and engagement which are vital determinants of learning performance in young learners. The mediation of engagement in academic success has been established as highly motivated students will find it easier to continue learning activities and attain higher performance levels.

Though the results are promising, there are various issues related to the AI-based methods of teaching that have been found in the literature. Such factors as inaccessibility to technological infrastructure, insufficient training of teachers, the problem of over-dependence on automated systems can influence the efficiency of AI implementation in the primary schools (Zawacki-Richter et al., 2019). Moreover, other researchers believe that AI must be used as an addition to the usual teaching methods, and teachers must still be crucial in helping students socialize and seek emotional support. The successful use of AI-based instruction methods should thus be ensured by a meticulous design of instruction as well as by correspondence to pedagogical objectives.

Critical analysis of the available literature demonstrates that there are significant gaps that require to be addressed by the way of additional research. To begin with, most studies are based on secondary or higher education settings, and few quantitative research papers are carried out to investigate AI-based teaching methods in the primary school. Second, a good fraction of the existing studies use qualitative or mixed-method designs that limit the generalizability of the results. Third, the empirical studies that use standardized pre-test and post-test design to objective measure of learning outcomes are lacking. These gaps reveal the necessity of the strict quantitative studies that will examine the direct effect of AI-based teaching methods on the learning performance of the primary school children.

Since AI is increasingly becoming a reality in educational institutions and especially in early education, there is a need to produce empirical evidence that will guide policy and practice. Quantitative research methods that assess the learning results are very informative about the usefulness of AI methods of teaching and evidence-based decision-making. Research in this field can also help to fill the current gaps in the literature, thereby making primary-school children experience improved learning and academic success through improved instruction strategies.

METHODOLOGY

Research Design

This research used the quantitative research design when it investigated the effects of AI-based teaching methods on the learning of primary school children. The quasi-experimental pre-test and post-test study design was chosen to assess the change in academic performance of students who were exposed to AI-based instructions methods. The quantitative method was chosen due to the possibility of objective measurement, statistical analysis, and generalization of results in the entire population of the study.

Population and Sample

The study population was comprised of primary school students who were taking grades 1-5. Six primary schools were used to draw the sample. The number of students engaged in the study was 300 individuals. The stratified random sampling was employed in order to have a proportional representation of the students at various grade levels. The students were separated into an experimental and a control group, based on the AI-guided instruction and traditional methods of teaching respectively.

Research Instruments

The data were gathered on the basis of structured achievement tests that were aimed at evaluating learning outcomes of students. The tools incorporated pre-test and post-test examinations in accordance to the curriculum goals of primary education. The examinations focused on the achievement of the students in the fundamental subjects such as mathematics and language studies. To achieve content validity, the instruments were subject to review by experts. A pilot study was done before data collection and reliability of the instrument was determined using Cronbach alpha coefficient.

Intervention Procedure

The experimental group had to be subjected to AI-based teaching methods during the course of eight weeks. Such methods were adaptive learning platforms, practice activities by AI, and intelligent feedback systems. The teaching material was created in a way that it matched the current curriculum and learning goals. The orientation of teachers on the use of AI-based tools was made prior to the commencement of the intervention. The control group went on with instruction using the traditional methods of teaching over the same period.

Data Collection Procedure

The collection of data was done in two stages. During the initial stage, pre-test was given to experimental and control groups in order to determine the level of baseline learning performance. A post-test was conducted on both groups after the period of intervention. The tests were also administered in the standardized conditions to achieve consistency and reduce the external effects on the performance of the students.

Data Analysis Techniques

Statistical software was used to analyze the data collected. The learning outcomes of the students were summarized using descriptive statistics such as mean and standard deviation. The AI-based teaching methods were tested using inferential statistical methods. To compare the pre-test and post-test scores, paired sample t-tests were applied, whereas, independent sample t-tests were implemented to compare experimental and control groups. The significant level was fixed at 0.05.

Ethical Considerations

Ethical considerations were strongly adhered to during the research. Before collection of data, permission was sought with authorities at the school. Parents or guardians of the participating students were informed about the study and gave informed consent. The identity of the participants remained confidential and the data obtained were utilized in the course of research.

DATA ANALYSIS

The data used in this research were processed in a systematic way in order to investigate the effectiveness of the AI-based instruction methods on the academic achievements of primary school students. Quantitative techniques were employed to conduct the statistical analysis, and thereby find the accuracy, objectivity, and reliability of the results. The data was filtered against missing information, outliers and entry errors prior to the main analyses. All of the answers were observed to be complete and were suitable to analyzing them, and there were no extreme outliers. Descriptive and inferential statistical analyses on the cleaned data set

was then delivered according to the research objectives and research questions. All tests of statistics were tested at a significant level of 0.05.

Early Data Pre-Testing and Assumptions Testing.

Before performing inferential statistical tests, some of the main assumptions of parametric analysis were discussed. The skewness and kurtosis were used to evaluate normality of data distribution. The values were within the range of acceptability which is +-1, which means that the data was normally distributed. Thompson showed that there was homogeneity of variance to ascertain comparability in the experimental and the control groups. The findings proved that the variance between groups was equal enough to conclude that the further analysis used t-tests. These pre-tests had ensured that the statistical procedures were the right procedures to use and that the results obtained were valid and reliable.

Descriptive Analysis of Learning Results.

The learning outcomes of the students were summarized using descriptive statistics which gave a general picture of performance trends in the experimental and control group. Results of pre-test and post-test were calculated to give mean scores and standard deviations. The pre-test results showed that the students in both groups were similar in terms of their baseline performance before the intervention implying that the two groups were similar in terms of their academic performance at the start of the study. This similarity enhanced the internal validity of the study since any differences that occur after the intervention could be ascribed to the teaching modes other than some existing academic differences.

The descriptive results of the post tests indicated that there was a significant improvement in the experimental compared to the control group. Students that were introduced to AI-based pedagogical methods showed greater means as well as reduced variability, which implies more consistent learning benefits. Conversely, the control group experienced a small amount of improvement implying that the use of traditional teaching methods did not produce a significant impact on the learning outcomes within the same period of time. These descriptive results gave preliminary indications of the beneficial nature of AI-based instructions in improving the learning outcomes of primary schools.

Comparison- between Groups Within-Group t-test

Paired sample t-tests were performed in order to investigate change in learning outcomes in each group. In this analysis, the experimental group (pre-test and post-test scores) was compared to identify whether AI-based techniques of teaching produced statistically significant improvement. The findings showed a vast improvement in the scores of the experimental group in the post-test which showed that that students had a significant improvement in their academic performance after the exposure to AI-supported instructions. The scale of improvement was an indication that AI-based instructional methods were effective in improving the understanding, retention, as well as acquisition of skills.

Conversely, the paired sample t-test of the control group showed that there was a minimal rise in the post test scores. This was not significantly different and it means that the conventional teaching and learning techniques failed to bring about any significant change in learning outcomes over the period of time. The comparison of in-group changes also demonstrated the efficiency of AI-based methods of teaching compared with traditional teaching methods.

Comparison of Groups One-Sample t-test

Independent sample t-tests were used to establish if there were any significant differences in learning outcomes between the experimental and the control groups based on post-test scores. This comparison was to evaluate the effectiveness of AI-based techniques of teaching in relation to the traditional teaching techniques. The findings showed that, there was a statistically significant difference between the two groups, where the experimental group scored much higher in the post-test compared to the control group.

This observation proved that an AI-based teaching method was more effective than a conventional teaching approach. The findings indicated that adaptive contents, real-time feedback and customized learning routes were some of the features that led to high academic achievement among primary school children. The comparison between the groups was quite empirical and supported the idea of the effectiveness of AI-based teaching methods in primary education.

Reliability Check of the Research Instrument

In order to achieve the consistency and reliability of the achievement test applied in this study, the reliability analysis was performed based on the alpha coefficient of Cronbach. The value of reliability was more than the minimum acceptable of 0.70 meaning that the instrument has high internal consistency. This finding validated the hypothesis of the test items measuring the same underlying construct and that the instrument was appropriate to measure learning outcomes. The reliability was high which enhanced credibility of the findings and served to guarantee that any differences in the scores through instructional effects were not a result of measurement error.

Statistical Findings Interpretation.

The general trend of the findings was that AI-based teaching methods used among the children in primary schools had a significant positive impact on learning. Students who were taught using AI showed better academic success, more performance consistency and significantly increased learning outcomes than students who were taught by traditional methods. The statistical results conformed to the descriptive trends, and this served to support the conclusion that AI-based teaching methods were viable in improving the learning outcomes.

Personalized and adaptive nature of AI-based instructions can explain the improvement that was seen in the research group. Having an immediate feedback and addressing the needs of individual learning, AI-based tools facilitated mastery learning and minimized learning gaps. These characteristics were especially useful to primary school students, who need formal instructions and support to build the background skills.

To conclude, the analysis of the data gave solid empirical evidence of the effectiveness of the AI-based teaching methods in primary school. The descriptive statistics were used to reveal the significant learning improvement among the students who received the AI-based teaching. Inferential analyses established that these were statistically significant improvements not only in the experimental group but also compared to that in the control group. The usage of reliability analysis also confirmed the consistency of the research instrument. Taken together, the results showed that AI-based instruction methods positively and significantly influenced the learning outcomes of children at primary schools.

Descriptive Statistics of Pre-Test and Post-Test Scores

Group	Test Type	Mean	Standard Deviation
Experimental Group	Pre-Test	62.45	8.32
Experimental Group	Post-Test	78.91	7.15
Control Group	Pre-Test	63.10	8.05
Control Group	Post-Test	66.28	7.89

DISCUSSION

The results of the current research proved that AI-based instructional methods demonstrated significant positive influence on the learning performance of primary school students. The findings disclosed that students who were subjected to AI-based teaching practices had significantly better post-test scores as opposed to those who were taught by conventional teaching methods. This is an improvement that indicates that the AI-driven teaching methods were successful in improving the performance of students as they receive personalized, adaptive, and interactive learning experience. These results confirm the accumulating literature on the use of AI to enhance instructional effectiveness and learning efficiency in learning environments.

The adaptive character of AI-based teaching methods can be deemed as the main contributor to the great enhancement that took place in the experimental group. The learning platforms supported by AI can tailor the instructional material according to the performance of the students and enable them to move at their own pace. This customized strategy fits the previous studies that imply that customized learning settings are associated with improved understanding and memorization, especially in a demographic of young-aged students who need constant reinforcement and feedback (Kulik and Fletcher, 2016; Holmes et al., 2021). The instant feedback that AI-based systems have offered probably helped students to overcome mistakes in real time hence making the concepts strong.

The results also represented that the traditional methods of teaching brought about a minimal change in the learning results of the students within the same time. The obtained outcome aligns with the previous research that indicates the inability of traditional teaching to meet various learning requirements in a classroom (Luckin et al., 2016). The traditional approaches tend to be based on the homogenous instruction, which might not be the most appropriate to the students with slower learning pace or with special needs. On the contrary, AI-driven instructional methods provide differentiated learning, which is why the latter are especially valuable in the primary school setting.

Moreover, constructivist and social constructivist learning theories support the results of this study. Constructivists view AI-based learning environments as promoting active learning and knowledge building by interacting with content (Piaget, 1952). In social constructivist perspective, AI-based systems operate as digital scaffolds by delivering direction in the areas of proximal development of learners (Vygotsky, 1978). The learning gains observed indicate that AI-based methods of teaching have been effective towards encouraging these theoretical learning processes.

In general, the results of this paper align with the findings of the empirical research that suggest the AI-based learning methods can improve student performance and student engagement. This study is relevant to the literature and offers quantitative data to prove the importance of introducing AI in the primary school environment. The findings highlight the relevance of carefully tailored AI-based learning as a tool of enhancing learning outcomes in the lower-level learning system.

CONCLUSION

The current study analyzed the effectiveness of AI-based instruction methods on the learning outcomes of children in primary school through a quantitative study method. The results showed that instruction using AI had a significant effect on the academic performance of the learners in comparison to the traditional instructional methods. Students who were introduced to AI-aided learning conditions could show an improved post-test score, which speaks of the better comprehension and mastering of the content of the subjects.

It was observed that AI-based instructional methods have significant pedagogical advantages in primary education. Individual-based learning needs were better served using AI-based tools compared to traditional classroom methods through personalized learning journey, adaptive learning, and instant feedback. The findings emphasized the importance of AI as a supportive learning tool that supports, but does not supersede, the conventional teaching methods.

This research study adds to the existing knowledge on the topic of educational technology by offering empirical data on the usefulness of AI-based teaching methods in the primary level. The results underscore the need to allow AI to be utilized in early education to enhance better learning experiences, as well as to equip students with the skills to overcome the growing opportunities of digital educational technology in the future.

RECOMMENDATIONS

There are some recommendations, which can be made based on the findings and conclusion of this study. First, schools must think about adopting AI-based methods of teaching at the primary school to improve the learning outcomes. The tools that are based on AI must be the supplementary instructional resources that may help teachers to provide individual and effective teaching.

Second, the teacher training programs must incorporate professional development programs in the field of the effective use of AI-based educational tools. Providing teachers with the relevant skills and experience will guarantee an effective implementation and the biggest possible instructional benefits of AI in primary classrooms.

Third, educational planners and policymakers need to allocate resources towards technological infrastructure that can facilitate the introduction of AI-based instruction methods especially in schools that are under-resourced. To have fair implementation and better educational results, the access to credible technology is required.

Lastly, the current study needs to be followed by further research that will investigate the long-term impacts of AI-based instruction methods on student learning and conduct other studies that consider other variables, including student motivation, cognitive maturity, and socio-economic status. Additional quantitative research in various educational settings will enhance the generalizability of the findings and lead to the evidence-based educational reforms.

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