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Analyzing the Impact of Augmented Reality on Student Motivation: A Time Series Study in Elementary Education

Herwin Herwin[1*], Lantip Diat Prasojo[1], Bambang Saptono[1], Shakila Che Dahalan[2]

[1] Department of Elementary School Education, Universitas Negeri Yogyakarta, Yogyakarta 55281, Indonesia
[2] Department of History, Universiti Pendidikan Sultan Idris, Perak 35950, Malaysia

Corresponding Author Email: herwin89@uny.ac.id

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ABSTRACT

Sub-optimal learning outcomes have been observed, often attributed to monotonous educational processes that struggle to retain students' focus and stimulate active participation. This study investigates the potential influence of Augmented Reality (AR) on student motivation, utilizing a time series analysis approach. The primary objectives include assessing the impact of AR on student learning outcomes and identifying the most suitable model for elucidating this relationship. The central research question is: can the implementation of AR enhance student motivation in elementary education? A time series design with a quantitative methodology was employed, involving a cohort of 29 fourth-grade students in Indonesia. Data collection was conducted through a Likert scale questionnaire. Four trend models were tested: the Linear Trend Model, Quadratic Trend Model, Growth Curve Model, and S-Curve Trend Model. The analysis of the collected data, tabulated and analyzed based on the established time series, suggests a positive correlation between AR technology implementation and student motivation. An upward trend in learning motivation was observed following the consistent application of AR technology in educational activities. Among the tested models, the Quadratic Trend Model demonstrated the least error estimate, with MAPE at 1.39, MAD at 1.08, and MSD at 1.44, suggesting it as the most suitable for further analysis related to the predictive power of student learning motivation in this context. This study advocates for the utilization of AR technology as an alternative method in classroom learning activities. The integration of learning content with game-like elements within a realistic world was observed to elicit student interest and enthusiasm. This approach is particularly recommended for educators seeking to enhance their students' learning motivation.

1. INTRODUCTION

The advent of globalization, marked by rapid advancements in information technology, has significantly transformed various aspects of human life, including education [1-4]. The necessity of embracing technological progression and its implications for education is a topic of ongoing discourse [5].

Previous literature has suggested that technological integration can enhance children's learning interest, offering diverse media displays to maintain attention and mitigate boredom [6]. This principle holds true in Indonesia's post-pandemic educational landscape, where technological applications in learning activities are frequently discussed in both academic and practical educational contexts [7].

The incorporation of technology in education often involves the use of modern applications developed to support theoretical and practical learning [8]. Numerous reports indicate that such integration has a positive impact on student success [9], enabling students to access information more easily [10]. This proposition is validated by the prevalent use of internet-enabled devices such as mobile phones and computers in schools.

However, the post-pandemic period has posed challenges related to student motivation. Many students appear to have lost their enthusiasm for learning, preferring gaming on smartphones over engaging with teacher-led lessons. This decrease in student engagement presents a significant issue, necessitating innovative solutions to enhance teaching effectiveness.

Augmented Reality (AR), defined as real-time representation of the real world enriched with computer-generated digital content [11, 12], could offer a solution. This technology enables students to interact with projected 2D or 3D virtual objects in a real-world context [13, 14].

AR has been deployed across various disciplines [15, 16] and has been shown to enhance learning effectiveness and educational goal attainment [17-19]. The choice of AR is predicated on its ability to present a realistic representation of objects in learning activities [20-23] and its compatibility with diverse devices, including desktops, tablets, smartphones, and Head-Mounted Displays [24-29].

Given these findings, this study proposes the implementation of AR in the learning process, aiming to make learning more engaging for students. The expectation is that an increase in learning interest will correspondingly improve learning outcomes.

This study seeks to perform a trend analysis of student learning motivation over seven time periods following the introduction of an AR-based learning program. Additionally, the study aims to identify the most suitable time series model

for analyzing the impact of AR technology on student learning outcomes. Such research is of significant value, contributing to the identification of optimal learning media for students and enhancing the quality of teacher performance in education.

2. METHOD

2.1 Types of research

This study uses a quantitative approach with a time series design. This study was conducted to test the effectiveness of Augmented Reality in learning activities. This media is applied based on a predetermined time series design. This timing follows the school's agenda schedule (so as not to disrupt the programmed system at school). In addition, effectiveness is measured by trends in student learning outcomes after participating in learning using Augmented Reality technology.

The time series technique used in this study was carried out seven times. Every time the implementation is carried out measurement of student learning motivation. Each full learning session is carried out for sixty minutes. However, the implementation of AR is limited to only about twenty-five minutes per session. AR applications have been integrated via smart phones and to add to the attractiveness of the content, researchers have prepared cardboard facilities for students.

2.2 Research subject

This research was carried out with a subject of 29 students. The subjects came from grade IV elementary school students in Indonesia. Furthermore, the subjects in this study were selected on the basis of the suitability of the content of the material to be taught. Each subject has a smart phone that is suitable for running the learning applications used. These students became the main subjects in this study as respondents who were directly subjected to learning treatment by applying Augmented Reality. Apart from students, the other subject is the teacher. The teacher in this study has the role of facilitating student learning. The intended assistance facility is implementing Augmented Reality in the learning program. This research was conducted in the 2021-2022 academic year.

2.3 Data collection technique

The main data collection in this study is a questionnaire guide. It is used to measure student learning motivation as many as twenty items with a Likert model scale. This technique is carried out to measure and obtain information related to trends in student motivation after participating in learning by applying Augmented Reality technology.

In addition, research data was also collected using observation techniques. This is done as a control over the learning process. The control in question is to ensure that the learning process is actually carried out according to the design by treating the treatment correctly. All research instruments used in this study have fulfilled content validity based on expert judgment and met reliability based on internal consistency.

2.4 Data analysis technique

The data analysis technique used in this study is trend analysis. This research data collection tool uses a Likert scale. The data that has been collected is based on measurements from the questionnaire, then tabulated and analyzed based on the time series that has been carried out in the field. This analysis tests four trend models. These models are the Linear Trend Model, Quadratic Trend Model, Growth Curve Model, and S-Curve Trend Model. To determine the ideal model, the measurement error estimation criterion is used. These criteria are the best model is the model that has the smallest measurement error. Mean Absolute Percentage Error (MAPE), Mean Absolute Deviation (MAD) and Mean Squared Deviation (MSD) approaches are used to analyze the estimation of measurement error in this study.

3. RESULTS

This study is focused on the application of Augmented Reality technology in the learning process carried out by teachers and students. This is based on initial findings indicating that there is a decline in student motivation in learning activities. By using Augmented Reality, the learning process is designed to provide nuances of learning that are more attractive to students. With this learning motivation is expected to increase and give a positive effect on the effectiveness of learning.

Basically, systematic learning is carried out as in general learning, namely starting with planning, implementation and evaluation. In planning the lesson, the teacher identifies the material to be conveyed to his students. This stage also includes determining competence and learning objectives. But what is special at this stage is that the teacher plans to integrate learning with Augmented Reality technology which is used in learning as a tool to help convey learning objectives to students. The subjects used in this study were twenty-nine students. As explained in the previous description, the implementation of the time series is carried out seven times. This is done to ensure identifying the best model, increasing the variance to find data saturation.

The next stage is the implementation of learning. The implementation of this learning is carried out periodically based on the lesson schedule that has been set in the school curriculum. The focus of this phase is the application of as a learning aid Augmented Reality helps convey learning material to learning targets. This can be observed in empirical findings in the field in the form of learning documentation.

Figure 1 shows the situation of the implementation of learning. After carrying out the implementation of these activities, an evaluation is carried out to measure the quality of the learning that has been carried out. In the interests of this research, the research only focuses on the variables of student learning motivation.

Based on previous information on the method, a measurement of students' learning motivation was carried out using a scale that had been prepared beforehand. After obtaining the evaluation results in the form of data on student learning motivation, the data is then tabulated for analysis using the trend analysis approach. As explained in the method section, this data is tested using four trend approaches, namely the Linear Trend Model, Quadratic Trend Model, Growth Curve Model, and S-Curve Trend Model. The results of the first analysis are presented based on a linear trend model. Based on the analysis of this first model, information on trends in student learning outcomes is obtained as follows.

Figure 1. Sample implementation of learning activities

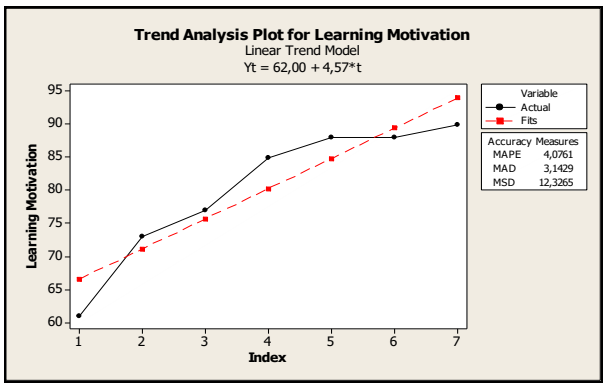

Figure 2. Student learning motivation based on linier trend model

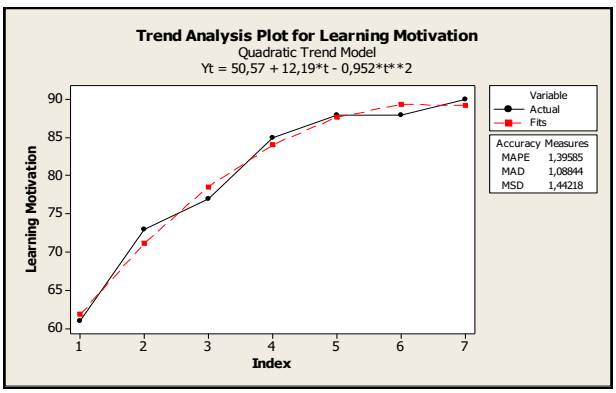

Figure 3. Student learning motivation based on quadratic trend model

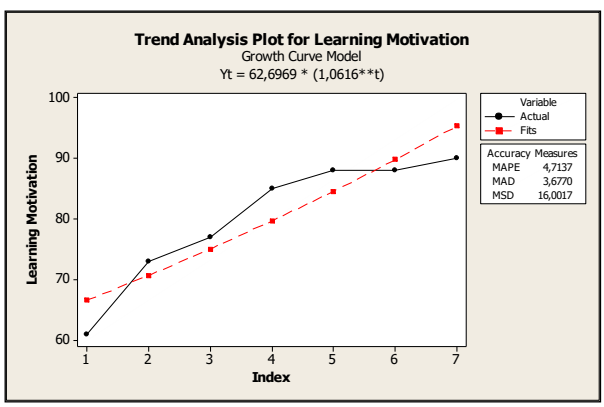

Figure 4. Student learning motivation based on growth curve model

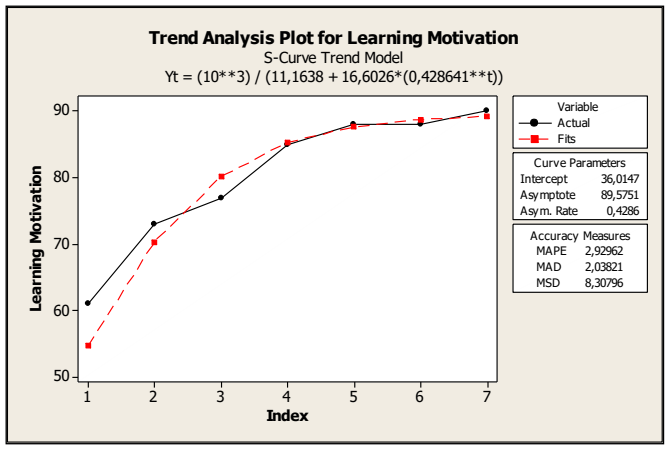

Figure 5. Student learning motivation based on S-Curve trend model

Figure 2 shows the findings of this study regarding student motivation based on the linear trend model. In the image you can observe two lines, namely red and black. The red line shows the expected fit or ideal model. While the black line is empirical data in the field. If viewed from the estimation of measurement error, it can be explained that in this model the MAPE is 4.07; MAD of 3.14; MSD of 12.32. The second analysis is continued by using the next model, namely the Quadratic Trend Model. The following are the results of these two findings.

Figure 3 shows the findings of this study regarding students' learning motivation based on the quadratic trend model. Based on this second analysis, the trend equation is obtained, namely: $Y_t=50.57+12.19^t–0.952t^2$. If viewed from the estimation of measurement error, it can be explained that in this model the MAPE is 1.39; MAD of 1.08; MSD of 1.44. Graphically, the best model is the model that is closer to the empirical data (black line) with the ideal model (red line). When compared with the previous model, it appears that this model is better in terms of graphics and measurement error. The third model analysis is the Growth Curve Model. In the following, the results of this model are presented.

Figure 4 shows the findings of this study regarding student motivation based on the growth curve model. Based on this third analysis, the trend equation is obtained, namely: $Y_t=62.69, 1.06^t$. If viewed from the estimation of measurement error, it can be explained that in this model the MAPE is 4.71; MAD of 3.67; MSD of 16.001. The last model analyzed in this study is the s-curve trend model. The following presents the results of the analysis based on the findings of the model.

Figure 5 shows the findings of this study regarding students' learning motivation based on the s-curve trend model. This model is the fourth analysis in this study. The trend equation obtained is: $Y_t=10^3/(11.16+16.6\ (0.42^t))$. If viewed from the estimation of measurement error, it can be explained that in this model the MAPE is 2.92; MAD of 2.08; MSD of 8.3.

After testing the four models being compared, the next step is to determine the best model to be used as a trend model for increasing student motivation based on Augmented Reality media. The following is a comparison recapitulation of the four models tested.

Table 1 shows the results of a comparison between the four trend models tested, namely Linear Trend Model, Quadratic Trend Model, Growth Curve Model, and S-Curve Trend Model. If viewed from the four models tested and the estimation of measurement errors used, it can be explained that

of the four models, the Quadratic Trend Model is the best model used to estimate trends in student learning motivation using Augmented Reality Technology media. This can be seen in Table 1 where the Quadratic Trend Model has the smallest measurement error estimation coefficient compared to the other three trend models. Therefore, it can be explained that the best trend equation model in this study is $Y_t=50.57+12.19^t–0.952t^2$.

Table 1. Recapitulation of the four models tested

Models	Error Estimation		
	MAPE	MAD	MSD
Linier Trend	4.07	3.14	12.32
Quadratic Trend	1.39	1.08	1.44
Growth Curve	4.71	3.67	16
S-Curve	2.92	2.03	8.3

4. DISCUSSION

This study discusses the quality of learning in terms of the application of digital technology in student learning activities and teacher teaching in elementary schools. The research findings explain that there is empirical evidence of using Augmented Reality Technology to improve the quality of student motivation in class. Various previous relevant studies have supported these findings, one of which concluded that Augmented Reality Technology is a suitable solution for arousing student motivation in learning [30, 31]. Based on several studies, Augmented Reality can trigger students' enthusiasm in participating in lessons and this has a direct impact on student learning motivation.

The development of information and communication technology must be utilized positively to maximize student learning. Through Augmented Reality, teachers can increase students' attention in learning and increase their learning motivation [32]. Through this media, teachers can also help students improve self-regulation [33]. Even with this media, teacher students can strengthen students' visual communication in learning [34, 35]. This is very good for students. Because with good visual communication students will pay more attention to following the subject matter and this has a direct impact on student learning motivation [36]. Previous research studies support the positive impact of Augmented Reality on student learning independence. This has a direct impact on learning that is centered on student activity, so that teacher domination is minimized in learning.

Choosing the right learning media is a trigger for maximum learning motivation [37]. Teachers must be able to make the right decisions related to learning media for their students. This is relevant to the findings of this study. Selection of Augmented Reality Technology is a good decision for teachers to increase their students' learning motivation. This media has very good characteristics to increase student motivation [38]. This characteristic is the integration of technological visualization which is associated with interesting games and shows in the world of children. Several studies explain that Augmented Reality is very suitable for the world of children because it can integrate interesting games into learning. This has an impact on diverting and focusing students' attention. If this is integrated with the subject matter, it is of course very beneficial in improving the quality of student learning activities.

Augmented Reality Technology is very suitable for children or elementary school students in learning activities. This is supported by its advantages, namely being able to combine several virtual objects such as 3D, video, images and sound into the real world [39, 40]. It's also quite easy to implement because it can be integrated directly with each student's Android device [41, 42]. With these advantages, teachers can help students improve their communication skills in learning [43]. This is very good and is the hope of all teachers for their students.

Augmented Reality is a technology that provides new experiences for students to interact with real objects and virtual objects [44]. This can support meaningful learning for students. With this experience, students will feel directly involved in learning and raise their enthusiasm for learning. If learning is meaningful, students will be enthusiastic. This situation has a direct impact on learning motivation.

In general, Augmented Reality Technology is very useful for learning activities [45-47]. This media makes a positive contribution to the effectiveness of student learning. In fact, the findings of this study empirically show that there is a positive trend in student learning motivation taught by this media. Not only learning motivation, but various studies have also reported that this technology is very good for increasing students' disciplinary character in learning [48], student attitudes [49] and students' understanding of learning concepts towards the material. It even has a direct impact on improving student learning outcomes [50, 51]. Several relevant studies also provide stronger support explaining that Augmented Reality technology does not only have an impact on student learning motivation, but also contributes to students' conceptual understanding which is directly related to increasing maximum learning outcomes.

Many previous relevant studies have confirmed that the application of technology to learning aids has a tendency to have a good impact and is useful for achieving goals in learning material [9, 52, 53]. Learning by utilizing this technology is even useful for strengthening positive character for elementary school students [54]. Based on some of the findings that have been discussed, it can strengthen this study that Augmented Reality is a learning media technology that is very useful for students. This is important because the ability to manage learning is an important part of the demands of teacher professionalism [55]. This media is recommended as an alternative in learning activities to increase students' learning motivation in elementary schools [56]. This means that if this technology is applied systematically through proper consideration, this tends to have a positive impact and helps in supporting a more optimal teaching quality in the future. Thus, the quality of learning activities in general can be improved.

5. CONCLUSIONS

This study concludes that Augmented Reality Technology has a positive effect on students' learning motivation at school. This is indicated by the positive trend of student learning motivation after being given learning by applying Augmented Reality Technology media. This confirms that Augmented Reality Technology is a good medium for teachers and students to increase student motivation in learning activities.

Augmented Reality is proven to be able to trigger student learning enthusiasm which is the main indicator of learning motivation. The problem of learning boredom and weak interest in learning can be overcome with this technology. With this technology, teacher dominance can be

proportionally controlled so that learning is more student-centered. This also directly has an impact on students' understanding of concepts that are better.

The findings of the analysis show that the Quadratic Trend Model is the most suitable model to be used for further analysis related to the predictive power of student learning motivation in this case study. The Quadratic Trend Model has the smallest measurement error estimation coefficient compared to the other three trend models. Therefore, it can be explained that the best trend equation model in this study is $Y_t=50,57+12,19^t–0,952t^2$.

This study recommends Augmented Reality Technology as an alternative in carrying out learning activities in the classroom. This media is recommended especially for teachers who want to increase their students' learning motivation. This media is recommended not only for increasing learning motivation, but this media is also very good for improving students' cognitive abilities and skills in learning, especially skills in integrating technology into learning activities.

This study has the strength of the repetition series which is considered methodologically sufficient. However, the addition of research subjects can be considered for future research. In addition, the expansion of student class level variants needs to be reviewed at other class levels.

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