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Development of Digital Education Based on *Starlink* Satellite Technology to Improve Students' Access to Online Learning In *Blank Spot Areas*

Ardi Rahmawan[1*], Puji Laila Ramadhan[2], Syaiful Islami[3], Nestika Ratum[4]
[1,3,4]STKIP Harapan Bima, Bima, Indonesia
[2]Universitas Nggusuwaru, Bima, Indonesia

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Abstract
This study was motivated by limited internet access in blank spot areas, which hinders online learning, reduces student participation, and affects learning outcomes, digital skills, and learning motivation. The purpose of this study was to analyze the implementation of Starlink satellite technology in improving students' access to online learning in blank spot areas. This research employed a Research and Development (R&D) method using the ADDIE model, consisting of analysis, design, development, implementation, and evaluation stages. Data were collected through interviews, observations, documentation, questionnaires, and pre-test and post-test assessments, then analyzed using a mixed methods approach. The results showed that Starlink implementation increased stable signal availability from 32% to 92%, internet access from 28% to 88%, and online learning smoothness from 35% to 90%. Students' average scores increased from 62 to 84, learning mastery from 45% to 85%, digital skills from 50% to 83%, and learning motivation from 55% to 88%. Therefore, Starlink is effective as an alternative solution to reduce the gap in online education access in blank spot areas.

Corresponding Author:
Ardi Rahmawan
STKIP Harapan Bima, Bima, Indonesia
Email: ardi.rahmawan2019@gmail.com

1. INTRODUCTION

Online education is the main solution to facilitate learning in remote areas, especially in Indonesia. Adequate internet access is essential for the success of online learning, but about 40% of areas in Indonesia are still not covered by fast and stable internet [1,2]. This hinders student participation and learning outcomes, due to limited infrastructure and technological skills [3,4]. Starlink satellite technology, developed by *SpaceX*, offers a solution by providing a fast and stable internet connection, even in remote areas. The use of these satellites can reduce the gap between urban areas and Blank Spot areas, providing greater opportunities for students in those areas to access education on par with more developed areas [5,6]. Thus, optimal access to online learning is an important factor in improving the quality of education in areas that have been digitally isolated.

Access to online learning is essential for students in *Blank Spot* areas, but many barriers stand in the way of achieving it. About 30% of students in remote areas are unable to access online education optimally due to lack of internet networks [7,8]. Only 25% of schools in rural areas can make effective use of online learning due to limited internet infrastructure and devices [9,10]. Data from the Ministry of Education and Culture shows that almost 40% of students outside Java have difficulty accessing online learning platforms, leading to academic lag [11,12]. Various government and private sector efforts, such as the provision of free internet access and device subsidies, have been made, but the main obstacle is limited network coverage and budget [13]. Although there are large projects such as Starlink, their implementation is still limited to a specific area and has not been evenly distributed throughout the Blank Spot area [14,15]. Therefore, equitable and effective access to online learning in these areas is still not fully achieved.

The problem of limited access to online learning in *Blank Spot areas* must be addressed immediately, as it can exacerbate the education gap between developed and disadvantaged areas [16]. Students who do not have adequate internet access will lag behind in learning, resulting in low learning outcomes and the quality of education in these areas [17]. Without a solution, the young generation in *the Blank Spot* area will lose out on educational opportunities on par with students in more developed areas, which can hinder social and economic progress [18]. A feasible solution is satellite technology such as *Starlink*, which is capable of providing fast and stable internet access in isolated areas [19]. *Starlink* can improve the quality of online education in Blank Spot areas, as it does not rely on cable infrastructure or cell towers [20]. Studies have shown that the use of satellite internet has a positive impact on the quality of education, allowing students to participate in learning without barriers [21,22]. The implementation of *Starlink* provides hope for reducing the digital divide and improving the quality of education in remote areas [23].

The application of *Starlink* satellite technology can provide fast and stable internet access in Blank Spot areas, allowing students in remote areas to access online learning seamlessly. With *Starlink*, the quality and speed of the internet improves, giving students the opportunity to acquire online educational materials and interact with teachers and friends. *Starlink* overcomes limited internet infrastructure constraints, enabling equal education throughout Indonesia. Therefore, it is important to evaluate the impact of *the implementation of Starlink* on online learning access and the quality of education in Blank *Spot areas*. Based on the background of the problem, the justification for the specific problem through the research of the new initiative is as follows: How does the implementation of Starlink reduce the gap in access to online education in Kota Bima Junior High School, as well as its impact on learning outcomes, digital skills, and student motivation?.

The approach proposed in this study is the application of *Starlink* satellite technology as a solution to improve access to online learning in the *Blank Spot area*. *Starlink* can provide stable and fast internet connectivity, even in areas that are not reached by conventional internet infrastructure, so that students in those regions can access learning materials online. Although this technology has been used in various sectors, its application to support online education in the *Blank Spot* area has never been specifically researched. Therefore, this study offers a new approach in addressing the gap in access to education in remote areas through *Starlink satellite technology*.

Previous research on access to online learning in remote areas has examined various approaches to address the digital divide. Most use mobile network-based approaches or wired infrastructure, such as 4G-based network models to improve online learning in rural areas [24,25,26]. Other studies evaluated community Wi-Fi use, but unstable connections hindered learning effectiveness [27,28,29,30]. Some studies also highlight blended learning models that combine online and face-to-face learning, but are still constrained by the limitations of internet infrastructure in Blank Spot areas [31,32,33]. Despite various efforts, most previous studies have not been able to solve the problem of access to online learning in the Blank Spot area. Unresolved issues are connection stability, affordability, and uneven internet distribution. The use of Starlink to improve the quality of online education in the

Blank Spot area has not been thoroughly researched. Therefore, the application of satellite technology, such as Starlink, is a solution to overcome this problem.

The novelty in this study lies in the application of *Starlink* satellite technology to provide stable and fast internet access in the Blank Spot area, which has never been applied in the context of online learning. Using *Starlink*, which offers a high-speed internet connection via satellite, the study aims to fill the gap by providing more effective and sustainable technology solutions for students in areas that are difficult to reach by conventional networks. The implementation of *Starlink* in online education is a new breakthrough that can accelerate the equitable distribution of access to education in blank spot areas, making it more affordable and effective for students who have been struggling to access online educational materials.

2. RESEARCH METHODS

2.1 Research Design

This study uses *the Research and Development (R&D)* method with *the ADDIE (Analysis, Design, Development, Implementation, Evaluation)* model [34,35]. This model was chosen because it is able to produce technology-based learning products that are structured and can be applied effectively in educational environments [36,37]. This research activity will be carried out at one of the Junior High Schools (SMP) of Bima City. There are three main stages in this research activity, namely; initial stage or preparation, implementation or implementation stage, final stage funds [38].

2.2 Data Collection Techniques

In this study, data collection techniques were carried out through several approaches in accordance with the *ADDIE model stage*, namely: in-depth interview techniques with teachers and students, observation of the learning process in the classroom, and documentation of student activities and the media used. The instruments used include interview guides, observation sheets, and visual documentation instruments such as photos and videos. In addition, tests in the form of pre-tests and post-tests are also used to measure students' learning skills, as well as *Likert* scale questionnaires to evaluate students' perceptions of the use of *Starlink* in online learning.

2.3 Data Analysis Techniques

The data analysis in this study was carried out in mixed *methods* which included qualitative and quantitative approaches [39]. The selection of this technique aims to accommodate all aspects in the research flow, from collecting data on the quality of internet access using *Starlink* to measuring its impact on online learning access. The analysis technique is prepared based on four main focuses that are in accordance with the formulation of the problem in this study, which are as follows: The data analysis in this study uses a mixed approach (mixed methods) with qualitative and quantitative analysis. Prototype Development Data Analysis was carried out by collecting data from observations, interviews with teachers and students, and field notes that were analyzed thematically to improve the Starlink-based online learning system. Product validity is analyzed using expert validation sheets on content, design, and technical aspects, with validity categories (very valid to invalid). The practicality of the product was measured through a questionnaire to students and teachers after the trial, and analyzed by descriptive statistics and triangulation of interviews and observations. Product effectiveness is measured by comparing pre-test and post-test results, using parametric (t-test) or non-parametric (*Wilcoxon*) statistical tests. Quantitative analysis was performed using SPSS software.

3. RESULT AND DISCUSSION

3.1 Research Result

3.1.1 Early Conditions of Access to Online Learning

Based on the results of initial data collection at the research site, the conditions of access to online learning in the *blank spot area* were obtained as follows:

Table 1. Early Conditions of Internet Access and Online Learning

No	Indicator	Value (%)	Category
1	Stable signal availability	32%	Low
2	Student internet access at home	28%	Low
3	Smooth online learning	35%	Low
4	Student engagement in online classes	40%	Medium
5	Availability of learning tools	45%	Medium

Data shows that the initial condition of access to online learning is still low. The lowest indicator is students' internet access at home at 28%, indicating that the majority of students cannot participate in online learning optimally. The smoothness of online learning only reaches 35%, which indicates that connectivity disruptions are very dominant. Student engagement is in the moderate category (40%), but still does not reflect effective learning.

3.1.2 Improved Access Results After Starlink Implementation

After the application of Starlink technology, a remeasurement was carried out on the same indicator.

Table 2. Conditions of Access to Online Learning After Starlink Implementation

No	Indicator	Value (%)	Category
1	Ketersediaan sinyal stabil	92%	Very High
2	Akses internet siswa di rumah/sekolah	88%	High
3	Kelancaran pembelajaran daring	90%	Very High
4	Keterlibatan siswa dalam kelas online	85%	High
5	Ketersediaan perangkat belajar	80%	High

Post-implementation results showed significant improvements across all indicators. The availability of stable signals increased dramatically to 92%, which indicates that Starlink is able to overcome network barriers in the blank spot region. Internet access increased to 88%, which means most students can now follow online learning consistently. The smooth learning reached 90%, showing that the stability of the learning system was optimal.

3.1.3 Comparison Before and After Implementation

To find out the changes in online learning conditions before and after the implementation of Starlink, a comparison was made of several main indicators. The indicators compared included stable signal availability, internet access, learning fluency, student engagement, and availability of learning devices. The results of the comparison are presented in Table 3 below.

Table 3. Comparison of Online Learning Conditions

Indicator	Before (%)	After (%)	Improvement (%)
Stable signal	32	92	+60
Internet access	28	88	+60
Smooth learning	35	90	+55
Student engagement	40	85	+45

Learning tools	45	80	+35

The comparison shows a significant improvement in all aspects. The biggest increase occurred in signal availability and internet access, which increased by 60% each. This shows that the implementation of Starlink has a direct impact on the equitable distribution of digital access. Student engagement also increased significantly by 45%, indicating an increase in participation in learning.

3.1.4 Improving Student Learning Outcomes (Pre-Test and Post-Test)

Student learning outcomes are measured through pre-test and post-test to determine the improvement of students' abilities after the implementation of Starlink. In addition to the average score, the measurement also includes learning completeness, digital ability, and student learning motivation. The results of these measurements are presented in Table 4 below.

Table 4. Student Learning Outcomes

No	Aspects	Pre-Test	Post-Test	Improvement
1	Average score	62	84	+22
2	Completeness of learning	45%	85%	+40%
3	Digital capabilities	50%	83%	+33%
4	Learning motivation	55%	88%	+33%

Student learning outcomes have increased significantly after the implementation of Starlink. The average score increased from 62 to 84. Learning completeness increased from 45% to 85%, indicating an improvement in the quality of material understanding. Digital skills and learning motivation have also increased by more than 30%, which shows that stable internet access has a direct impact on improving the quality of learning.

3.1.5 Diagram of the Results of Starlink's Application to Online Learning

The results of the study can be illustrated through the following diagram.

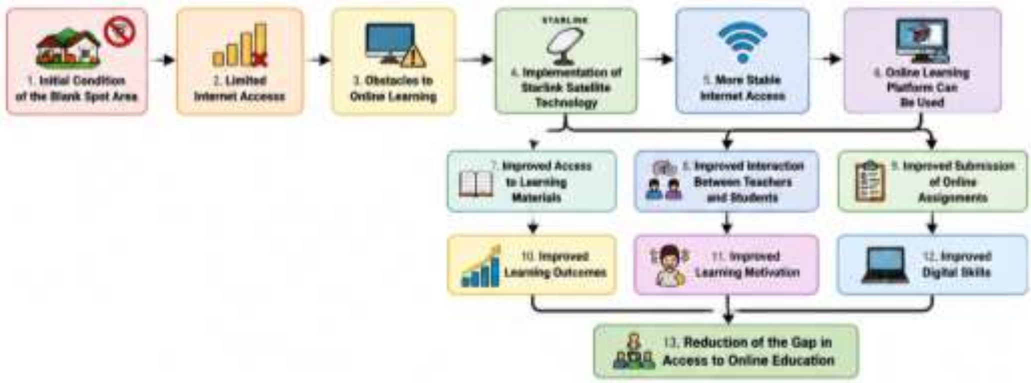

Figure 1. Diagram of the Results of Starlink's Application to Online Learning

The diagram shows that the initial condition of the study started from the existence of Blank Spot areas that experienced limited internet access. These limitations cause online learning to not run optimally. The application of Starlink satellite technology is a solution used to improve internet access. Once internet access becomes more stable, online learning platforms can be used by teachers and students. The use of the platform encourages increased access to learning materials, increased interaction between teachers and students, and increased online assignment delivery. The impact of the process can be seen in three main aspects, namely improving learning outcomes, increasing learning motivation, and improving students' digital skills. These three aspects are interrelated in supporting the reduction of the gap in access to online education. Thus, the implementation of Starlink not only solves technical problems in the form of network limitations, but also affects the learning process and outcomes of students.

3.2 Discussion

3.2.1 Early Conditions of Access to Online Learning

The data from the study shows that the initial condition of access to online learning at SMP Negeri 15 Bima City is still in the low category, especially in the indicator of internet access of students at home which only reaches 28% and the availability of stable signals at 32%. This condition shows that students in blank spot areas do not have adequate connectivity support to participate in online learning regularly and continuously. The low flow of online learning by 35% shows that the learning process is still affected by network disruptions, limited platform access, and communication barriers between teachers and students. These findings are in line with a study on the digital divide which confirms that the digital readiness of students and schools is an important factor in determining the success of online learning [40,41]. Thus, the low initial access not only shows technical problems, but also illustrates the inequality of learning opportunities that has a direct impact on the quality of student participation.

The involvement of students in online classes, which only reaches 40%, shows that the presence of technology does not automatically result in learning participation if the internet network and learning support are not equally available. The availability of learning devices at 45% also shows that digital access for students is not only determined by the network, but also by the readiness of the device and the ability to use learning media. In this condition, students who do not have a device or stable connection tend to experience delays in receiving materials, difficulty collecting assignments, and lack of activity in discussions. This is in line with the findings that the challenges of online learning include the learning environment, technological literacy, the availability of devices, and the ability of institutions to manage network-based learning [42,43]. Therefore, the initial conditions of the study show the need for technological interventions that not only provide internet access, but also encourage the readiness of students and teachers to utilize online learning effectively.

3.2.2 Improved Access After Starlink Implementation

After the implementation of Starlink, stable signal availability increased to 92%, internet access to 88%, and smooth online learning to 90%. This improvement shows that low-orbit satellite technology is capable of being an alternative solution for areas that are not reached by conventional cable or cellular networks. The change also confirms that connectivity is a basic prerequisite for the digital learning process, as stable internet access allows students to open materials, attend classes, and interact with teachers more consistently. Studies of low-orbit satellite constellations show that modern satellite systems are designed to provide global broadband services, particularly in areas experiencing terrestrial infrastructure constraints [44,45]. Thus, the increase in access indicators after the implementation of Starlink can be understood as evidence that geographical barriers in blank spot areas can be reduced through the use of satellite technology.

Although the results show a high increase, the use of Starlink still needs to be understood as part of a learning system that must be managed in a sustainable manner. The increase in the smooth learning to 90% indicates an improvement in connection quality, but the success of online learning still depends on network stability, device readiness, classroom settings, and teacher mentoring. Starlink's network measurement studies show that this technology promises broad coverage, but its performance can still be affected by environmental conditions, latency dynamics, weather, and network configuration. These findings are important comparisons because this study is not enough to assess the increase in access, but also to assess the sustainability of the use of Starlink in daily learning activities [46,47]. Therefore, the results of increasing access must be positioned as a strategic opportunity that still requires learning management, device maintenance, and periodic technical evaluation.

3.2.3 Comparison Before and After Implementation

Comparisons before and after implementation show that the largest improvements occurred in stable signals and internet access, by 60% each. This improvement shows that the main problem at the research site is indeed centered on limited connectivity, not solely on the low interest of students. A 45% increase in student engagement reinforces the understanding that better internet access can open up spaces for interaction, accelerate the distribution of materials, and increase students' chances of being active in learning. Research on educational technology shows that the use of technology can increase behavioral, affective, and cognitive engagement when supported by the right learning design [48,49]. Thus, the increase in student engagement after Starlink shows that access to technology is the gateway to the formation of a more meaningful online learning experience.

The 35% increase in learning devices also shows that connectivity interventions encourage more productive use of devices in learning activities. Prior to implementation, the available devices could not be utilized optimally because the network was unstable and platform access was often interrupted. As internet access improved, learning devices went from being just a support tool to being the primary means of accessing materials, working on assignments, participating in discussions, and receiving feedback. Meta-analyses of online and distance learning show that the effectiveness of digital learning is strongly influenced by the quality of interaction, teacher involvement, and the design of learning activities that combine technology with pedagogical strategies [50,51]. Therefore, the increase in numbers after implementation not only illustrates the success of technology, but also shows that technology needs to be integrated with targeted learning practices.

3.2.4 Improving Student Learning Outcomes

Pre-test and post-test data showed an increase in the average student score from 62 to 84, or an increase of 22 points. The increase in learning completeness from 45% to 85% shows that stable internet access contributes to the understanding of the material and the completion of learning activities. This result can be explained by increased opportunities for students to access learning resources, repeat materials, interact with teachers, and complete assignments more in a timely manner. Studies on digital readiness and technology acceptance show that the success of technology-based learning is influenced by the perception of usefulness, ease of use, academic engagement, and readiness of students in the e-learning environment [52,53]. Thus, the increase in post-test scores in this study can be understood as a combined impact between the availability of internet access, increased digital readiness, and improved quality of learning interactions.

The increase in students' digital abilities from 50% to 83% shows that Starlink not only serves as a network provider, but also opens up opportunities for students to practice using learning technology. Students who were previously limited in accessing online platforms began to have hands-on experience in searching for materials, using learning applications, submitting assignments, and communicating digitally. The increase in learning motivation from 55% to 88% also shows that ease of access can foster students' confidence and interest in learning. The study of digital literacy confirms that the ability to plan, search, evaluate, and manage digital information is related to learning success, while ICT self-efficacy plays an important role in shaping students' confidence in the use of technology [54,55]. Therefore, the improvement of digital skills and learning motivation in this study shows that network interventions are able to produce pedagogical impacts when students are given the space to use technology directly.

3.2.5 The Effectiveness of Starlink Implementation in Online Learning

The results show that the implementation of Starlink is more effective when combined with online learning platforms and Project-Based Learning methods. This combination allows students not only to passively receive material, but also to work on activities, complete projects, discuss, and gain a more contextual learning experience. Increased engagement and learning outcomes suggest that network technologies need to be placed as part of the learning ecosystem, rather than as the ultimate goal of research. Studies on mobile learning and learning analytics show that educational technology yields better results when its use is associated with learning activities, progress monitoring, and support for student needs [56,57]. Thus, the results of this study confirm that the success of Starlink in online learning is determined by the integration between access, activity design, classroom management, and continuous evaluation.

Overall, the results of the study show that the implementation of Starlink is able to answer the main problem in the form of limited access to online learning in blank spot areas. Increased access, engagement, learning outcomes, digital skills, and learning motivation show that satellite technology can be a strategic alternative to reduce digital education inequality. However, this success needs to be maintained through teacher training, strengthening students' digital literacy, device management, and periodic network quality monitoring. Studies on independent learning and social presence in online learning show that long-term success is determined by students' ability to manage their learning as well as the quality of social-academic interaction in a digital environment [58,59]. Therefore, this discussion emphasizes that Starlink is not only a connectivity solution, but also an instrument for equitable learning that must be supported by pedagogical strategies, resource readiness, and continuous evaluation.

4. CONCLUSION

Based on the results of the study, the application of Starlink satellite technology can be a strategic solution to reduce the gap in access to online education for students in white spot areas. More stable internet connectivity allows the online learning process to take place more smoothly, regularly, and can be followed by students without the barriers of the dominant network. The improved access shows that the main problem of the research, namely the limitations of internet infrastructure, can be answered through the use of satellite technology that does not depend on cable networks or cell towers. The implementation of Starlink also strengthens the use of online learning platforms because teachers and students have a more consistent interaction space in accessing materials, discussing, and sending assignments. The impact of learning that arises is not only related to the technical aspects of connectivity, but also seen in the increasing readiness of students to use digital technology to support learning activities. Improved learning outcomes show that adequate internet access plays an important role in opening up opportunities for students to understand the material better and participate in learning more actively. In addition, students' motivation to learn becomes stronger because online learning can take place more easily, responsively, and in accordance with learning needs in areas that previously experienced limited access. Thus, the application of Starlink in this study proves that satellite technology can be an instrument for equitable distribution of digital education if integrated with learning design, teacher mentoring, and continuous evaluation. In conclusion, the development of Starlink-based digital education is feasible as an alternative model to improve online learning access, learning outcomes, digital skills, and student motivation in blank spot areas.

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