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Enhancing Programming Learning through a Smartphone-Based Asynchronous Flipped-Learning Media

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Abstract

Purpose: This study aims to develop and evaluate a smartphone-based asynchronous flipped-learning media application called BEST (Belajar Struktur Data) to support programming and algorithm learning in higher education during online learning conditions.
Methodology: This research employed a research and development approach using the ADDIE model, which consists of analysis, design, development, implementation, and evaluation stages. The application was implemented with 40 Informatics Engineering Education students at Universitas Muhammadiyah Surakarta. The evaluation involved black-box testing, compatibility testing using Firebase Test Lab, expert validation using Aiken's V from two media experts and one material expert, and usability testing using the System Usability Scale (SUS).
Results: The results showed that the BEST application achieved a 100% success rate in functional and compatibility testing. The Aiken's V value obtained from both media and material expert validation was 0.89, indicating that the learning media is valid and feasible. The usability evaluation produced a SUS score of 71.8%, which reflects an acceptable level of usability and high student satisfaction.
Applications/Originality/Value: This study contributes an original smartphone-based asynchronous flipped-learning media specifically designed for programming education, offering a practical solution to overcome technical limitations in synchronous online learning and supporting more flexible, independent, and engaging learning experiences in higher education.

Introduction

The implementation of large-scale social restrictions by the Indonesian government in response to the Covid-19 pandemic since early 2020 has rendered face-to-face learning infeasible in many regions (Wiryono, 2020). In line with this condition, the Indonesian Ministry of Education mandated the implementation of online learning at all levels of education (Kasih, 2020). At the higher education level, Universitas Muhammadiyah Surakarta suspended on-site learning activities and fully transitioned to online learning starting from the end of the 2019/2020 even semester. To support this transition, the university conducted training programs for lecturers on the use of learning management systems and the development of digital instructional materials to ensure the continuity and quality of the learning process.

Despite these efforts, the abrupt shift to online learning due to the pandemic introduced several challenges. Ma (2020) identified common problems in online learning, including: (1) the increased demands on educators, who are required not only to deliver instruction but also to manage online classes, particularly during synchronous sessions, while maintaining student engagement; (2) the high level of self-discipline required from learners, as poor time management may lead to missed learning materials; and (3) the need for significant adjustments in curriculum design, teaching strategies, and assessment methods compared to conventional face-to-face instruction.

Blended learning has been proposed as a viable solution to sustain the learning process during the pandemic (Sukmawati et al., 2020). One prominent model within blended learning is flipped learning, which restructures traditional instructional practices by placing learners at the center of the learning process and enabling flexible asynchronous and synchronous activities (Lanjuan et al., 2020). Several studies have attempted to integrate flipped learning with other pedagogical approaches to enhance its effectiveness in online learning environments, such as project-based learning (Rahman et al., 2017) (Francese et al., 2015) and problem-based learning (G. Wang et al., 2019).

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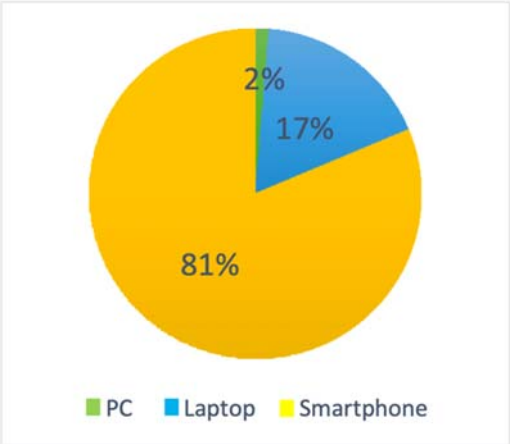

Figure 1. Percentage of device use in learning

However, the application of flipped learning in its various forms still encounters technical obstacles during synchronous sessions conducted via video conferencing. Based on a questionnaire administered to 75 Information Engineering Education students in June 2020, internet limitations emerged as the main issue, leading to unclear audio and video reception and, in some cases, disconnection from the video conferencing platform. As a result, many students reported that they found it easier to engage with learning materials during asynchronous sessions and preferred to use synchronous sessions primarily for discussion and reinforcement of concepts. In addition, the questionnaire results indicated that more than 80% of students relied on smartphones as their primary device for online learning, as illustrated in Figure 1. This finding aligns with previous studies showing that smartphones can be effectively utilised within flipped-learning models, particularly during asynchronous activities (Baharum et al., 2019).

Flipped learning is one of the instructional approaches that can be effectively integrated into online learning environments (Ma et al., 2024), wherein students are expected to first engage in independent learning during asynchronous sessions before participating in teacher-facilitated synchronous sessions (Baharum et al., 2019).. Through this process, learners construct understanding based on their own experiences, while educators assume the role of facilitators who provide guidance when students encounter difficulties with the material or assigned tasks. The flipped-learning model adopted in this study follows the DLTS (Do, Learn, Think, Share) framework proposed by (W. T. Chen et al., 2018), whose research demonstrated that flipped learning can effectively enhance students' creativity in science-related learning contexts.

Nevertheless, the implementation of flipped learning in programming courses presents specific challenges. (Assiri, 2016), through a survey of 182 students, found that many learners did not understand how a program operates, largely because they lacked prior exposure to programming. The study also revealed that presenting programming language concepts from a single perspective made it difficult for students to transfer their understanding to other programming languages. This condition may conflict with the flipped-learning requirement that students study independently. Consequently, (Suo, 2012) recommends that programming concepts be decomposed into smaller tasks framed as problem-solving activities so that students can concentrate on resolving problems using their own strategies.

After identifying an appropriate instructional concept for teaching programming within a flipped-learning model, the next question concerns the form of problem-solving to be implemented. One relevant study is that of (Guanghui et al., 2018), who employed case studies to teach programming concepts using a chessboard scenario. In this approach, students were required to write Python code to move chess pieces, thereby learning programming through contextualised tasks.

Other studies have introduced problem-solving activities through visual approaches, as demonstrated by (Taylor et al., 2019), (Chiu, 2020), (Yoshihara & Watanabe, 2016) and (Poole, 2015). Many of these works employed block-based programming environments to introduce fundamental programming concepts. Their findings suggest that block-based programming can effectively enhance students' interest and engagement in learning programming.

A number of researchers have also explored the use of gamification and game-based learning for teaching programming, including studies by (Montes-Leon et al., 2019) (Abbasi et al., 2018) (Özer et al., 2018) and (Silva & Silveira, 2020). Gamification refers to the application of game elements in non-game contexts to address specific problems, whereas game-based learning involves the design of games explicitly intended to support teaching and learning processes. (Ab. Rahman et al., 2018) argue that both gamification and game-based learning are particularly suitable when implemented using user-friendly technologies such as e-learning platforms.

The development of augmented reality and virtual reality (AR/VR) technologies has also been integrated into educational settings. Although AR/VR is not always designed as a direct problem-solving tool, it can provide learners with enriched and immersive learning experiences(Y. Chen et al., 2019). Studies by (Sunil & Nair, 2017) and (G.-J. Chen & Chen, 2018) indicate that the use of AR as an instructional medium can increase students' activeness and critical thinking in the learning process.

The final approach that informs this research is a problem-solving strategy based on live coding (Hung, 2018). In conventional face-to-face settings, live coding involves designing and implementing a project in real time in front of the class during instruction (S. Wang et al., 2020). This approach is typically followed by opportunities for students to independently experiment with and modify the demonstrated code, and has been shown to improve learners' programming skills.

The present study aims to leverage the strengths of asynchronous sessions within the flipped-learning online model and to optimise students' use of smartphone technology by developing a flipped-learning media application. This research will be conducted with Informatics Engineering students enrolled in a programming and algorithm course.

Method

This study employed the ADDIE development model (KeskiN & Yilmaz, 2020). ADDIE is widely recognised as an appropriate framework for research and development (R&D) studies due to its systematic design, which facilitates a well-structured product development process. As illustrated in Figure 2, the ADDIE model consists of five sequential phases, namely Analyze, Design, Development, Implementation, and Evaluation. The cyclical nature of this model enables the development process to be conducted in a more organised and iterative manner.

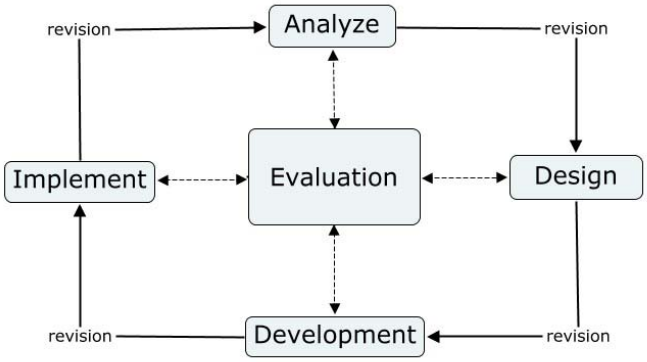

Figure 2. The ADDIE Model Cycle

1. Analysis

At this stage, the researchers conducted interviews with student respondents. The findings revealed several technical problems during flipped-learning activities conducted through video conferencing, which made it difficult for students to effectively understand and follow the learning process. These conditions indicate the need for innovation in providing flexible and user-friendly learning media for students. In addition, it is essential to align the learning media with the devices predominantly used by students.

2. Design

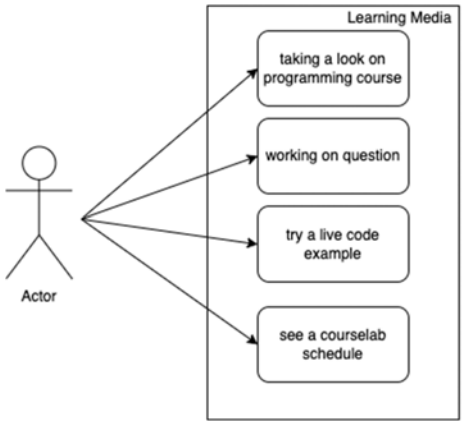

Figure 3. Use Case Diagram

During the design phase, the researchers developed an initial plan to facilitate the product development process in accordance with the identified needs and product specifications. This phase covered the selection of development techniques, data collection methods, product testing procedures, and the preparation of learning content. The design

outcomes served as a guideline for the implementation of the product development. The design in this study includes a product use case, as presented in Figure 3.

3. Development
At the development stage, the researchers developed the learning media application. The application contains theoretical materials related to data structures, instructional videos that explain the presented content, and additional features in the form of quizzes to assess users' understanding. The product was developed using Kodular block-based programming as a tool for creating Android-based learning media.

4. Implementation
The BEST learning media was implemented in the programming algorithm practicum course involving 40 students of Universitas Muhammadiyah Surakarta as the primary target users. At this stage, the learning media was utilised as the main instructional medium for students during the practicum course.

5. Evaluation
At the evaluation stage, the researchers assessed the performance and functionality of the developed application. The evaluation included black-box testing, media expert validation conducted by two lecturers of Informatics Engineering Education, material expert validation conducted by one lecturer teaching the algorithms and programming course, and usability testing using the System Usability Scale (SUS) involving 40 UMS students. This evaluation was carried out to determine whether the BEST learning media effectively addressed learning problems in the asynchronous flipped-learning model through the use of the developed application.

Result and Discussion

This study resulted in the development of a learning media application called BEST (Belajar Struktur Data), which was designed to support distance learning for students at Universitas Muhammadiyah Surakarta (UMS). The application aims to assist students of the Informatics Engineering Education Study Program who are enrolled in programming and algorithm courses in understanding router installation and configuration procedures. In addition, the learning media is equipped with features that present learning content in the form of videos, images, instructional materials, and quizzes, as illustrated in **Figure 4**.

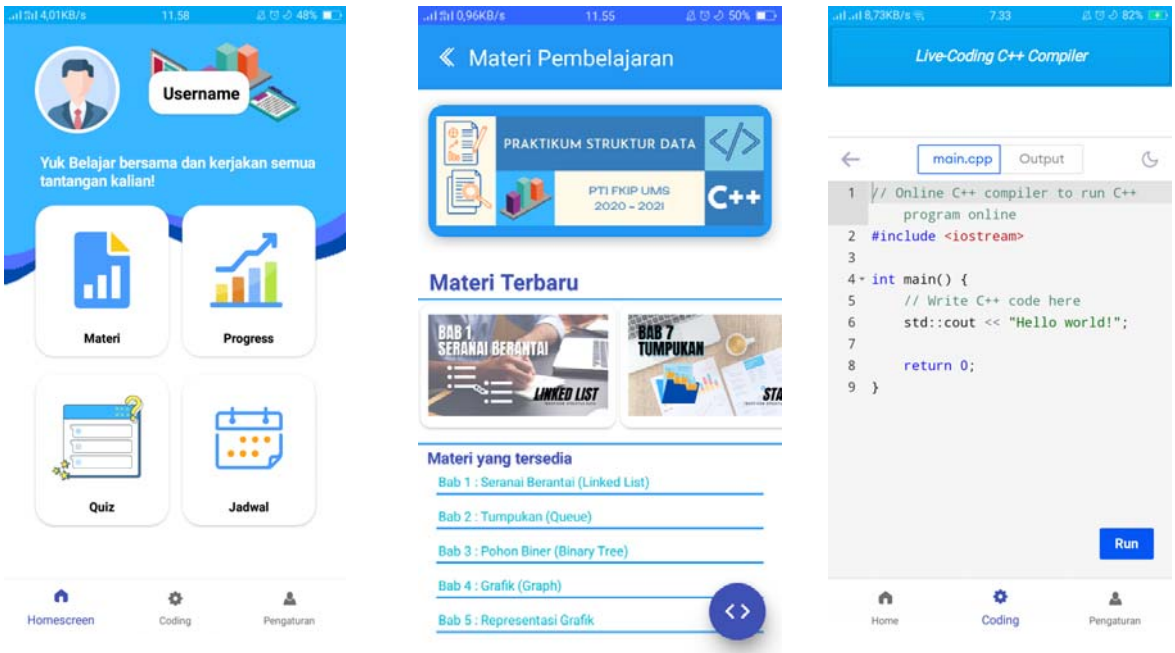

Figure 4. User Interface of BEST learning media

Black-box testing was conducted to evaluate the functional performance of the developed learning media, particularly in terms of functional correctness, alignment with user requirements, and overall system capability. This testing was carried out through questionnaires completed by media experts and professionals with expertise in software engineering, with the purpose of assessing the suitability and reliability of the system functions. The results of the black-box testing conducted by the media experts are presented in Table 1.

Table 1. Result of Blackbox Testing

Number of Test	Running	Failed
10	10	0
Presentase	100%	0%

Based on the results shown in Table 1, it can be concluded that the learning media achieved a 100% success rate in the black-box test. All system functions operated as intended, and the instructions provided to the system were executed properly and in accordance with the researcher's expectations.

In addition to functional testing, a compatibility test was conducted using Firebase Test Lab to determine whether the developed learning media could operate properly across different types of mobile devices, as presented in Table 2. The results in Table 2 indicate that the compatibility test reached a 100% success rate, which means that the learning media ran smoothly on all four tested smartphone brands or series available in the Firebase Test Lab environment.

Table 2. Firebase Test Lab Method

Test	Running	Failed
Smartphone Instalation	4	0
Application Running	4	0
Presentase	100%	0%

Based on the evaluation conducted by media experts, the validity analysis was calculated using the Aiken's V formula as presented earlier. The assessment data were obtained from two expert respondents who evaluated the learning media based on predefined assessment indicators. The overall Aiken's V coefficients were calculated for all items, and the average value was derived from the two respondents' ratings. The resulting V coefficients across the evaluated items showed relatively consistent values. According to the Aiken's V critical value table, for 20 assessment items, the acceptable validity range is indicated by a lower limit of 0.63 and an upper limit of 0.93, with a reference V value of 0.83. In this study, the obtained Aiken's V value reached 0.89, indicating that the content validation by media experts falls within the acceptable range. Therefore, the learning media can be classified as valid based on media expert judgment.

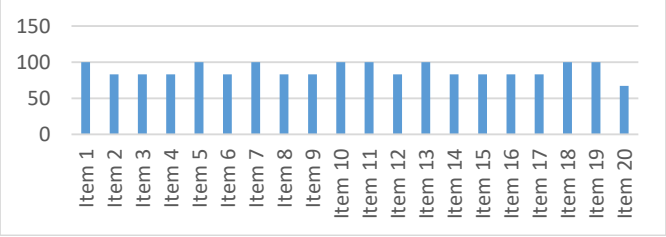

Figure 5. Media Expert Interpretation

Figure 5 presents the graphical interpretation of the validation results, where learning media are considered feasible if the V value lies between 0.63 and 0.93 or exceeds the reference value of 0.83. The processed data from items 1 to 20 yielded an average validity percentage of 89%, indicating that all evaluated items are suitable for reuse.

Furthermore, validation by material experts was also analyzed using the Aiken's V formula. The data were collected from one material expert who assessed the learning media based on 23 evaluation items. The overall Aiken's V coefficients were calculated for each item, and the resulting values showed a relatively uniform distribution across all items. Referring to the Aiken's V table for 23 items, the validity threshold is indicated by a lower limit of 0.74 and an upper limit of 0.98, with a reference V value of 0.92. The obtained Aiken's V value in this evaluation was 0.89, which still falls within the acceptable validity range. Thus, the learning media is considered valid based on material expert assessment.

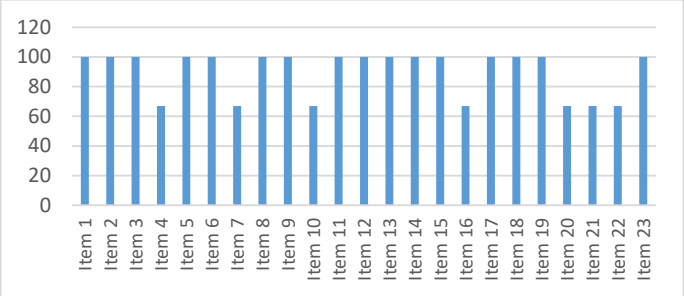

Figure 6. Material Expert Interpretation

Figure 6 illustrates the interpretation graph of the material expert validation results. The feasibility of the learning media is determined by whether the V value meets or exceeds the lower threshold of 0.74. The processed data from items 1 to 23 produced an average validity percentage of 89%, indicating that all assessment items are feasible and appropriate for further use.

The usability evaluation was conducted using the System Usability Scale (SUS) questionnaire, which was distributed to 40 students selected randomly from seven programming practicum classes in the Informatics Engineering Education Study Program at Universitas Muhammadiyah Surakarta. All respondents were students who had previously used the developed learning media. Based on the calculation of the SUS scores obtained from the 40 respondents, an average usability score of 71.8% was achieved. This result indicates that users have a high level of satisfaction with the developed learning media, and it can be interpreted that the system falls within the acceptable category in terms of usability and user experience.

The results of this study demonstrate that the BEST learning media has successfully met functional and technical requirements, as indicated by the perfect score achieved in both black-box testing and compatibility testing using Firebase Test Lab. A 100% success rate in functional performance confirms that all system features operated as designed and aligned with user needs. Furthermore, the compatibility test results indicate that the application can run reliably across different smartphone brands, which is particularly important given that more than 80% of students rely on smartphones as their primary learning devices.

From the perspective of content and media quality, the Aiken's V validation results confirm that the BEST learning media is valid and feasible for instructional use. The media expert evaluation produced a V value of 0.89, exceeding the minimum validity threshold, while the material expert validation also yielded a V value of 0.89, which falls within the acceptable range. These results indicate that both the technical design and instructional content of the application meet established quality standards. The high average validity percentage of 89% across all evaluated items further suggests that the learning media is suitable for continued use and potential wider implementation.

In terms of user experience, the System Usability Scale (SUS) score of 71.8% indicates that the BEST learning media falls within the acceptable usability category and reflects a high level of user satisfaction among students. This result suggests that students were able to use the application effectively without significant difficulty, which is a critical factor in the success of technology-enhanced learning. The positive usability outcome also reinforces the potential of BEST as a practical solution to address the technical limitations commonly encountered during synchronous online learning, such as unstable internet connectivity.

The findings of this study are consistent with previous research highlighting the effectiveness of flipped learning in online environments. (G. Ma, 2020) and (Baharum et al., 2019) emphasized that flipped learning enables students to engage with learning content asynchronously before participating in synchronous sessions focused on clarification and discussion. This learning pattern aligns closely with the way BEST is utilized by students, where core materials are accessed independently through smartphones, while synchronous sessions are optimized for reinforcement. Furthermore, the smartphone-based implementation of BEST supports the conclusion of (Baharum et al., 2019) that mobile devices play a critical role in facilitating flexible learning within flipped-classroom settings. This confirms that the design of BEST is pedagogically appropriate for supporting asynchronous flipped learning in higher education.

In addition, the problem-solving orientation embedded in the BEST learning media is supported by several relevant studies. (Suo, 2012) emphasized that programming concepts should be broken down into small problem-solving tasks to accommodate students with limited programming backgrounds, a condition also identified by (Assiri, 2016). The use of structured instructional videos, quizzes, and step-by-step learning materials in BEST reflects this recommendation. Moreover, previous studies by (Guanghui et al., 2018) and (Taylor et al., 2019) demonstrated that contextualized and visual problem-solving approaches, including case-based and block-based programming, significantly improve student engagement and understanding. The positive usability results of BEST, as reflected by the SUS score, further support the argument that interactive and mobile-accessible problem-solving media can enhance students' learning experiences in programming courses.

Conclusion

This study concludes that the BEST (Belajar Struktur Data) learning media is a valid, reliable, and feasible solution for supporting asynchronous flipped learning in programming and algorithm courses. The application successfully met functional and technical standards, as evidenced by a 100% success rate in both black-box and compatibility testing. In addition, content and media validation using Aiken's V confirmed that the instructional materials and system design meet established quality criteria, while the usability evaluation, reflected by a SUS score of 71.8%, indicates a high level of student satisfaction and effective system use. These findings demonstrate that smartphone-based asynchronous learning media can optimize the implementation of the flipped-learning model, particularly in overcoming technical constraints commonly encountered during synchronous online learning. For future work, further studies are recommended to examine the impact of BEST on students' learning outcomes through experimental or quasi-experimental designs. The application can also be enhanced by incorporating adaptive learning features, learning analytics, and real-time feedback mechanisms to support personalized learning. Moreover, expanding its implementation across different programming courses and institutions, as well as integrating emerging technologies such as gamification, augmented reality, or artificial intelligence-based tutoring systems, offers promising directions for further development and wider validation.

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