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Development of an Interactive Learning Media for Elementary Students' Non-Locomotor Motions Using ML Kit Pose Estimation

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ABSTRACT

The rapid advancement of technology has created opportunities to improve physical education through interactive learning media. This study aimed to develop an interactive learning media application using ML Kit pose estimation to support the learning of fundamental non-locomotor movements among elementary school students. The study employed the Research and Development (R&D) method using the ADDIE model. The product was validated by one learning expert, one subject-matter expert, and one media expert, and implemented with one physical education teacher and 19 elementary school students at MIN 24 Aceh Utara. Data were collected through validation questionnaires, observations, interviews, and system performance testing. Quantitative data were analyzed using descriptive percentage analysis, while qualitative data were used to support product evaluation. The results showed that the developed media was highly feasible, with validation scores of 95% from the learning expert, 93% from the subject-matter expert, and 98% from the media expert. The pose estimation system achieved an accuracy of 99.56% in detecting students' non-locomotor movements. The application provided real-time visual feedback to support movement accuracy and student engagement. In conclusion, the developed interactive learning media is highly feasible and technically accurate for supporting the teaching of fundamental non-locomotor movements in elementary schools. The integration of ML Kit pose estimation provides an innovative approach to enhancing interactive and technology-assisted physical education learning.

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INTRODUCTION

Physical education at the elementary school level plays an essential role in developing students' fundamental motor skills, physical fitness, and active lifestyles. At this stage, children require appropriate movement-based learning experiences to support their physical and cognitive development (Zulnadila, 2024). Among fundamental movement skills, non-locomotor movements, such as bending, twisting, swinging, and stretching, are basic competencies that provide the foundation for more advanced motor abilities (Wahyuni, 2022). Therefore, effective and engaging learning strategies are needed to help students master these skills.

Despite their importance, teaching non-locomotor movements in elementary schools remains challenging. Physical education teachers commonly rely on conventional instructional methods, including direct demonstrations and verbal explanations, which may not effectively accommodate students with different learning styles (Rendot, 2021; Masudi, 2024). Many students require visual learning resources, immediate feedback, and interactive learning experiences to understand and perform movements correctly (Parkinson et al., 2009; Ayeni et al., 2024; El-Sabagh, 2021). Consequently, students often have difficulty distinguishing between correct and incorrect movement techniques, which may hinder the development of their fundamental motor skills.

Advances in educational technology provide opportunities to address these challenges. One promising technology is pose estimation, which enables automatic detection and analysis of human body movements through camera-based systems (Song & Chen, 2024). By providing real-time feedback on movement performance, pose estimation can improve learning accuracy and student engagement in physical education (Yang & Jia, 2022). In particular, Google's ML Kit offers pose detection capabilities that support the development of interactive learning applications with high movement recognition accuracy (Roggio, 2024; Paolucci, 2023).

The need for innovative learning media is also supported by preliminary observations conducted at Madrasah Ibtidaiyah Negeri 24 Aceh Utara. Interviews with physical education teachers revealed that students experienced difficulties in performing non-locomotor movements correctly because learning activities mainly depended on teacher demonstrations and verbal explanations. In addition, the limited availability of instructional media prevented teachers from providing immediate and objective feedback, making movement errors difficult to identify during practice.

Previous studies have demonstrated that pose estimation technology is effective for human movement analysis, sports performance evaluation, and rehabilitation (Samkari et al., 2023; Effendi et al., 2023). Other studies have utilized digital videos or multimedia applications to support physical education learning. However, these studies generally focused on movement analysis or conventional digital learning media without integrating real-time pose estimation, interactive instructional content, and automatic movement assessment into a single learning platform. Furthermore, the application of ML Kit pose estimation for teaching fundamental non-locomotor movements at the elementary school level has received limited attention.

To address this research gap, the present study develops an interactive learning media application using ML Kit pose estimation for elementary school students' non-locomotor movements. The developed application integrates digital learning materials, camera-based movement practice, real-time feedback, automatic movement evaluation through image or video uploads, and learning history records. Unlike previous studies, this research combines artificial intelligence-based pose estimation with interactive learning media to provide objective movement assessment while supporting independent learning. This integration is expected to improve students' understanding and performance of non-locomotor movements and contribute to the development of technology-enhanced physical education in elementary schools.

METHOD

This study employed a Research and Development (R&D) approach to develop and evaluate an interactive learning media application using ML Kit pose estimation for teaching fundamental non-locomotor movements in elementary schools. The study adopted the ADDIE instructional design model, consisting of five stages: Analysis, Design, Development, Implementation, and Evaluation (Branch, 2010). The ADDIE model was selected because it provides a systematic framework for developing and evaluating educational products that meet users' learning needs (Hidayat & Nizar, 2021).

During the analysis stage, observations and interviews were conducted with a physical education teacher at Madrasah Ibtidaiyah Negeri 24 Aceh Utara to identify learning problems, students' needs, curriculum requirements, and existing instructional media. The findings served as the basis for designing the learning media.

The design stage involved preparing the learning content, user interface, system architecture, and assessment framework. In the development stage, the application was created by integrating digital learning materials, real-time camera-based pose estimation, automatic movement evaluation, and learning history features. The pose estimation model was developed using Google ML Kit Pose Detection to recognize fundamental non-locomotor movements.

The developed product was validated by three experts, consisting of one learning expert, one subject-matter expert, and one media expert. Validation was conducted using structured questionnaires based on a five-point Likert scale covering instructional design, content accuracy, interface design, functionality, usability, and technical performance. Suggestions from the experts were used to revise and improve the application before implementation.

The implementation stage involved one physical education teacher and 19 elementary school students at Madrasah Ibtidaiyah Negeri 24 Aceh Utara. Students used the application to learn and practice fundamental non-locomotor movements, while the teacher observed the learning process and evaluated the application's usability. The student participants performed the specified non-locomotor movements using the developed application under the same testing procedures and movement instructions.

Data were collected through observation, interviews, expert validation questionnaires, and system performance testing. Quantitative data from the validation questionnaires were analyzed using descriptive percentage analysis to determine the feasibility level of the developed media. The feasibility criteria were categorized as very feasible (81–100%), feasible (61–80%), fairly feasible (41–60%), less feasible (21–40%), and not feasible (0–20%). Qualitative data obtained from observations, interviews, and expert comments were analyzed descriptively to support product revision and evaluation.

The pose estimation system was evaluated using a total of [number of test data] movement samples obtained from the 19 student participants. The testing covered the four targeted non-locomotor movements, namely [list the four movements used in the accuracy test]. Each movement was performed according to the predefined movement instructions, and the system analyzed the detected body landmarks and movement patterns in real time. A movement was classified as "correct" when the detected pose satisfied the predefined joint-angle and movement-pattern thresholds, whereas movements that did not meet the specified criteria were classified as "incorrect."

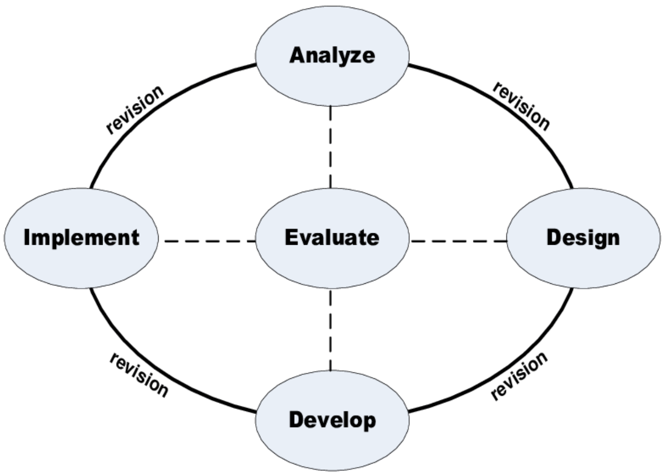


Figure 1. ADDIE model steps

The 99.56% accuracy was calculated by comparing the system's predicted movement classifications with the corresponding reference or expected classifications across all test samples. The overall accuracy was calculated as the proportion of correctly classified movement samples divided by the total number of tested samples, multiplied by 100%. The testing was conducted under [describe testing scenario, e.g., real-time camera conditions / uploaded video / image-based testing], with [describe relevant conditions, e.g., camera position, distance, lighting, and movement duration] kept consistent across the testing sessions.

RESULTS AND DISCUSSION

An interactive learning media application based on ML Kit pose estimation was successfully developed to support the learning of fundamental non-locomotor movements in elementary schools. The application consists of four main features: Learn Movements, Practice, Evaluation, and History.

The Learn Movements feature provides instructional materials through text, images, videos, audio guidance, and safety instructions. The Practice feature employs a real-time camera to detect body landmarks using ML Kit pose estimation and provides immediate feedback on students' movement performance. The Evaluation feature automatically assesses movement accuracy based on uploaded images or videos, while the History feature records students' learning progress and assessment results.

Figure 2. App's Feature

Results in Producing Media One of the core components of the development process is the ML Kit-based pose estimation model, which was implemented to recognize fundamental non-locomotor movements such as bending, flexing, stretching, and swinging. The model was developed using a relevant movement dataset and calibrated through threshold adjustments to accurately identify students' poses. This stage was conducted to ensure that movement detection could operate in real time and provide appropriate feedback to support the learning process. Additionally, the implementation of the pose estimation model enables a more objective assessment of students' movement performance and enhances the interactivity of the learning media.

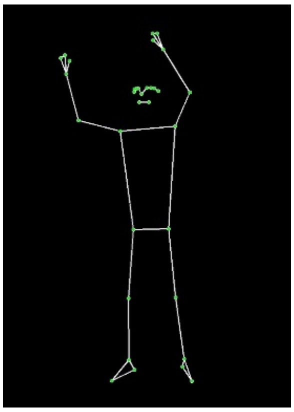


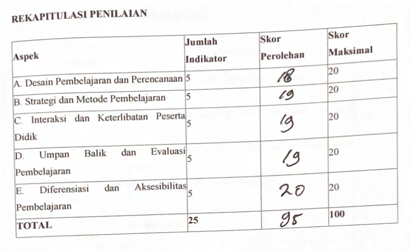
Figure 3. Motion Landmark Display

Figure 4. Student Movement Display with Landmark Pose Estimation

The development results show that the pose estimation model used has a very high accuracy rate of 99.56%. This figure is a significant achievement, demonstrating that the model is capable of detecting poses with a very low error rate. With this high accuracy, the learning media becomes more reliable and can support students in correctly learning non-locomotor movements without experiencing misidentification. In developing the user interface, the design was child-friendly, featuring bright colors, large buttons, and intuitive navigation. This approach aims to enable students to operate the application independently without requiring much assistance from teachers. Initial testing results indicated that students could navigate the application easily, thus deeming the interface design effective.

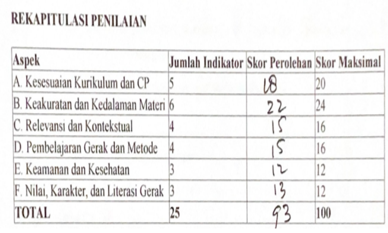
Media Validation Results

Based on the validation results from the learning expert, subject matter expert, and media expert, the design stage demonstrated a very high level of feasibility, with overall feasibility percentages of 95% (learning expert), 93% (subject matter expert), and 98% (media expert). These results indicate that the design components, including instructional design, learning content, navigation structure, user interface, and media interaction flow, were considered highly appropriate for supporting the teaching and learning of fundamental non-locomotor movements in elementary schools. From the instructional design perspective, indicators such as the clarity of learning objectives, the suitability of learning strategies for interactive media, and the logical sequence of content presentation received very high scores (18/20). This finding suggests that the learning module was designed in accordance with scaffolding principles and effectively supports the achievement of students' movement competencies. Furthermore, the visual, audio, and animation elements were developed to align with the learning characteristics of elementary school students, particularly those who benefit from kinesthetic and visual learning approaches.



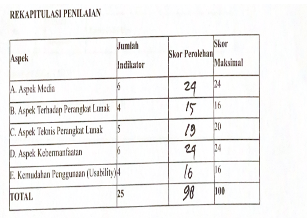
REKAPITULASI PENILAIAN

Aspek	Jumlah Indikator	Skor Perolehan	Skor Maksimal
A. Desain Pembelajaran dan Perencanaan	5	18	20
B. Strategi dan Metode Pembelajaran	5	19	20
C. Interaksi dan Keterlibatan Peserta Didik	5	19	20
D. Umpan Balik dan Evaluasi Pembelajaran	5	19	20
E. Diferensiasi dan Aksesibilitas Pembelajaran	5	20	20
TOTAL	25	95	100



REKAPITULASI PENILAIAN

Aspek	Jumlah Indikator	Skor Perolehan	Skor Maksimal
A. Kesesuaian Kurikulum dan CP	5	18	20
B. Keakuratan dan Kedalaman Materi	6	22	24
C. Relevansi dan Kontekstual	4	15	16
D. Pembelajaran Gerak dan Metode	4	15	16
E. Keamanan dan Kesehatan	3	12	12
F. Nilai, Karakter, dan Literasi Gerak	3	13	12
TOTAL	25	93	100



REKAPITULASI PENILAIAN

Aspek	Jumlah Indikator	Skor Perolehan	Skor Maksimal
A. Aspek Media	6	24	24
B. Aspek Terhadap Perangkat Lunak	4	15	16
C. Aspek Teknis Perangkat Lunak	5	19	20
D. Aspek Kebermanfaatan	6	24	24
E. Kemudahan Penggunaan (Usability)	4	16	16
TOTAL	25	98	100

Figure 5. Learning Validator **Figure 6.** Material Validator **Figure 7.** Media Validator

From the content perspective, the validation results indicated that the design of the non-locomotor movement materials was aligned with the Learning Outcomes of the Merdeka Curriculum, the intended Learning Objectives, and fundamental kinesiology principles. All indicators related to content accuracy, including movement descriptions, body keypoint positioning, and physiological explanations of movement, received excellent scores (22/24). These findings confirm that the developed content is not only curriculum-aligned but also scientifically accurate.The application's interface and technical design were also rated as highly feasible by the media expert, achieving a score of 98%. The highest ratings were obtained for layout organization, clarity of pose detection visualization, camera response speed, and ease of menu navigation. The system was designed to display pose estimation results in real time, provide immediate feedback, and generate automatic evaluations that are easily understood by students. Furthermore, the organization of the "Learn Movements," "Practice," "Evaluation," and "History" menus was carefully designed to facilitate a systematic and independent learning process.

Table 1. Information on Students' Reactions to Media

No	Student Name	Maximum Score	Acquisition Score	presentation	Category
1	AS	80	80	100%	Sangat Praktis
2	AM	80	75	94%	Sangat Praktis
3	ASK	80	80	100%	Sangat Praktis
4	AN	80	80	100%	Sangat Praktis
5	DM	80	78	98%	Sangat Praktis
6	IA	80	79	99%	Sangat Praktis
7	MS	80	80	100%	Sangat Praktis
8	MAP	80	78	98%	Sangat Praktis
9	MAN	80	77	96%	Sangat Praktis
10	MAF	80	78	98%	Sangat Praktis
11	MF	80	80	100%	Sangat Praktis
12	MSI	80	79	99%	Sangat Praktis
13	NK	80	75	94%	Sangat Praktis
14	NS	80	78	98%	Sangat Praktis
15	NL	80	79	99%	Sangat Praktis
16	SN	80	80	100%	Sangat Praktis
17	UM	80	78	98%	Sangat Praktis
18	SI	80	79	99%	Sangat Praktis
19	MA	80	80	100%	Sangat Praktis
	Total	1520	1493	98%	Sangat Praktis

CONCLUSIONS

This study successfully developed an interactive learning media application using ML Kit pose estimation to support the teaching of fundamental non-locomotor movements for elementary school students. The expert validation results indicate that the developed media is highly feasible in terms of instructional design, content quality, and technical functionality, demonstrating its suitability for use in physical education learning. The integration of pose estimation technology enables real-time movement analysis and automatic feedback, providing a more objective and interactive learning experience than conventional instructional methods. The main contribution of this study lies in integrating artificial intelligence-based pose estimation with interactive learning media specifically designed for elementary physical education. This integration supports students' independent practice, assists teachers in movement assessment, and offers an innovative approach to teaching fundamental non-locomotor skills.

Nevertheless, this study has several limitations. The implementation was conducted in a single elementary school and focused only on four types of non-locomotor movements. In addition, the effectiveness of the developed media was primarily evaluated through expert validation and system performance testing, without comparing students' learning outcomes with those achieved through conventional instructional methods.

Therefore, future studies should involve larger and more diverse participant groups, include a wider range of movement skills, and conduct experimental or quasi-experimental studies to examine the effectiveness of the media in improving students' motor skills, learning motivation, and learning outcomes. Further development may also incorporate adaptive feedback and learning analytics to enhance the functionality of AI-based physical education learning media.

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