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EFFECT OF TECHNOLOGY-BASED SMART MUSIC BOXING MEDIA ON MANIPULATIVE MOTOR SKILLS OF ELEMENTARY SCHOOL TEACHER EDUCATION STUDENTS AT UNIMED

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ABSTRACT

Physical education requires innovative technology-based learning media to support the development of manipulative motor skills among prospective elementary school teachers. This study aimed to examine the use of technology-based Smart Music Boxing media and its relationship with the manipulative motor skills of students in the Elementary School Teacher Education Study Program, Faculty of Education, Universitas Negeri Medan. A quantitative approach was employed using a quasi-experimental method with a nonequivalent control group pretest–posttest design. The participants were students enrolled in an elementary school physical education course and were assigned to an experimental group, which received instruction using Smart Music Boxing media, and a control group, which received conventional instruction. Data were collected using a punch speed test, target accuracy test, rhythm synchronization test, and combination punch test. Descriptive and inferential statistics were used to analyze the data after the analytical assumptions had been examined. The results showed increases in the experimental group's mean scores across all measured skill components. Punch speed increased from 65.51 to 84.94, target accuracy from 66.34 to 84.80, rhythm synchronization from 67.00 to 84.71, and combination punching from 67.37 to 85.26. Students also demonstrated greater participation, enthusiasm, and engagement during the learning process. These findings suggest that Smart Music Boxing may serve as an alternative technology-based learning medium to support the development of manipulative motor skills among prospective elementary school teachers.

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INTRODUCTION

Mastery of manipulative motor skills such as throwing, catching, kicking, and striking provides a fundamental basis for coordination, agility, readiness for sports participation, and students' long-term academic achievement ((Jones et al., 2020); (Sutapa et al., 2021); (Webster et al., 2019)). In the Elementary School Teacher Education (PGSD) Study Program, Faculty of Education, Universitas Negeri Medan, prospective teachers are expected not only to understand theoretical concepts but also to develop pedagogical content knowledge and practical skills so that they can serve as accurate movement models for their pupils. However, observations indicate that the manipulative motor skills of PGSD students have not yet developed optimally. This condition is associated with the student population, which is predominantly female, and with their relatively limited prior experience and participation in physical activity and motor practice during earlier stages of education. In response to the demands of the Society 5.0 era, the strengthening of the Outcome-Based Education (OBE) curriculum, and the study program's digital technology-oriented academic vision, innovation is needed in elementary physical education through the use of engaging, adaptive, structured, and immersive digital-intelligent technologies (He et al., 2024); (Komlo, 2025); (Suriatno, 2024); (Zhong et al., 2025).

Previous studies have shown that boxing training can improve punching techniques (Chrysagis et al., 2024), while the integration of interactive media, sensors, and music can support the development of coordination, accuracy, and reaction speed (Barkasi et al., 2024); (Goncalves et al., 2024); (Haleem et al., 2022); (Zulfikar et al., 2022); (Rosi et al., 2025); (Rutkowski et al., 2021); (Siregar et al., 2023). Nevertheless, the existing literature generally focuses on school-age children, practicing teachers, or athletes and has not yet integrated punch sensors, musical rhythm, and interactive LED visuals into a single learning medium for higher education. The novelty of this study lies in the use of Smart Music Boxing media, which applies a tri-modal sensorimotor learning approach by simultaneously combining proprioceptive stimuli (motion sensors), auditory stimuli (rhythmic music), and visual stimuli (LED feedback) (Effenberg et al., 2016); (Stein & Rowland, 2011). This integration is specifically designed for PGSD students to bridge two competencies: personal motor skill mastery and readiness to design technology-based movement instruction.

Based on this background and rationale, this study aimed to analyze the manipulative motor skill levels of PGSD students at FIP, Universitas Negeri Medan, before the intervention (pretest), assess their skills after the intervention (posttest), and empirically examine the effect of technology-based Smart Music Boxing media on the improvement of

their manipulative motor skills. Through this evaluation process, the study is expected to provide practical contributions in the form of guidelines for using the media and recommendations for implementing innovative learning strategies in physical education at both higher education institutions and elementary schools.

RESEARCH METHODS

This study employed a quasi-experimental method with a pretest–posttest control group design. This design was selected because the researchers could not fully randomize the participants, as the students were already organized into established classes. Nevertheless, the design allowed a comparison of the intervention between the experimental and control groups (Hastjarjo, 2019).

The study population comprised all second-semester students enrolled in the PGSD Study Program, Faculty of Education, Universitas Negeri Medan, in the 2025/2026 academic year. The independent variable (X) was technology-based Smart Music Boxing media (experimental group), while the dependent variable (Y) was manipulative motor skill.

Four main performance tests (Table 1) were integrated with the features of the Smart Music Boxing machine and combined with a rubric- and norm-based scoring system that had been validated for the student population (Lovric et al., 2019); (Putro et al., 2024).

Table 1. Manipulative Motor Skill Performance Tests

No.	Test Name	Description	Duration	Assessment Indicators
1	Punch Speed Test	Students punch targets that light up randomly on the Smart Music Boxing machine.	60 seconds	Number of accurate punches Average reaction time Speed consistency
2	Target Accuracy Test	Students punch specific targets according to visual/audio instructions.	90 seconds	Accuracy percentage Hand positioning accuracy Movement coordination
3	Rhythm Synchronization Test	Students punch targets in time with the music being played.	120 seconds	Synchronization with the musical beat Rhythm consistency Movement fluency

No.	Test Name	Description	Duration	Assessment Indicators
4	Combination Punch Test	Students perform a combination of punches (jab, cross, hook, and uppercut) according to the displayed pattern.	90 seconds	Complex movement coordination Sequence accuracy Execution speed

Pretest and posttest data from the experimental and control groups were analyzed by calculating the mean, standard deviation, minimum value, and maximum value. These analyses were used to identify trends in changes in students' motor skills and provided the basis for subsequent analyses.

Before hypothesis testing, the data were examined to determine whether they met the assumptions for parametric statistical analysis. The examination included a normality test to assess whether the data were normally distributed and a homogeneity of variance test to determine whether the two groups had comparable data distributions. Meeting these assumptions provided a basis for proceeding with further analyses.

Conceptually, homogeneity was tested using Levene's test with statistical software. An equivalence test of baseline ability was also conducted by comparing the pretest scores of the two groups using an independent-samples t-test.

Because the main hypothesis was tested using analysis of covariance (ANCOVA), the linearity of the relationship between pretest and posttest scores and the homogeneity of regression slopes across the two groups were examined. These tests were intended to ensure that the relationship between baseline ability (the covariate) and the final score (the dependent variable) was linear and met the assumptions for ANCOVA (Khammar et al., 2020).

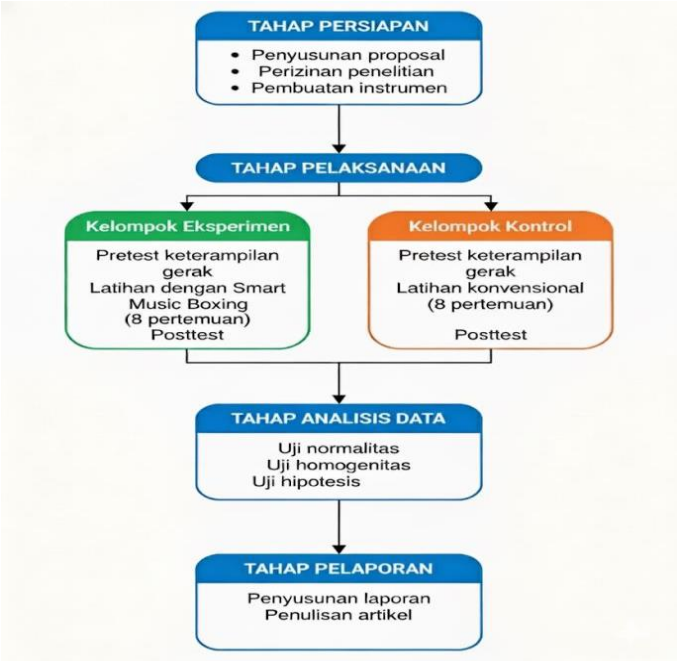


Figure 1. Research Flowchart

RESULTS AND DISCUSSION

Descriptive statistical analysis was conducted to provide an overview of the research data. The analysis included the mean, standard deviation, minimum, and maximum values for the pretest and posttest scores of both groups.

Table 2. Descriptive Statistical Analysis of the Experimental Group's Pretest Scores

Variable	N	Minimum	Maximum	Mean	Std. Deviation
Punch Speed Test	35	61	73	65.51	3.00
Target Accuracy Test	35	61	73	66.34	3.57
Rhythm Synchronization Test	35	61	73	67.00	3.15
Combination Punch Test	35	61	73	67.37	3.77

As shown in Table 2, the descriptive analysis of the pretest data from 35 students showed that manipulative motor skills across the test components were generally at a moderate level. For the Punch Speed Test, the minimum score was 61 and the maximum score was 73, with a mean of 65.51 and a standard deviation of 3.00. This indicates that students' baseline ability to punch quickly was relatively low, while the scores showed limited dispersion.

For the Target Accuracy Test, the minimum score was 61 and the maximum score was 73, with a mean of 66.34 and a standard deviation of 3.57. This result indicates that students'

ability to hit a target accurately before the intervention was not yet optimal, although variation in scores among students was relatively small.

For the Rhythm Synchronization Test, the minimum score was 61 and the maximum score was 73, with a mean of 67.00 and a standard deviation of 3.15. The mean score indicates that students' ability to synchronize punching movements with musical rhythm was at a moderate level and had not yet developed optimally.

For the Combination Punch Test, the minimum score was 61 and the maximum score was 73, with a mean of 67.37 and a standard deviation of 3.77. This result indicates that students' ability to perform sequential punching combinations still required improvement, although the relatively small standard deviation suggests limited score dispersion.

Overall, the descriptive analysis indicates that students' baseline manipulative motor skills were relatively homogeneous, with scores ranging from 61 to 73 across all test components. The relatively small differences among the mean scores suggest that students had comparable initial ability levels. This provides an overview of the participants' baseline characteristics before comparing learning outcomes between the experimental group, which received instruction using technology-based Smart Music Boxing media, and the control group, which received conventional instruction.

Descriptive Statistical Analysis of Posttest Scores

The descriptive analysis of the posttest data from 35 students indicated an increase in manipulative motor skill performance following instruction using technology-based Smart Music Boxing media. For the Punch Speed Test, the minimum score was 80 and the maximum score was 90, with a mean of 84.94 and a standard deviation of 3.19. Compared with the pretest mean of 65.51, the score increased by 19.43 points. This indicates an improvement in students' reaction speed and consistency when punching the target.

For the Target Accuracy Test, the minimum score was 80 and the maximum score was 90, with a mean of 84.80 and a standard deviation of 3.11. Compared with the pretest mean of 66.34, the score increased by 18.46 points. This improvement indicates that students became more capable of punching with greater accuracy after participating in technology-based instruction.

For the Rhythm Synchronization Test, the minimum score was 80 and the maximum score was 90, with a mean of 84.71 and a standard deviation of 3.36. Compared with the pretest mean of 67.00, the score increased by 17.71 points. This result indicates that students became more capable of synchronizing their punching movements with the music and

visual stimuli presented by Smart Music Boxing, thereby improving movement coordination.

For the Combination Punch Test, the minimum score was 80 and the maximum score was 90, with a mean of 85.26 and a standard deviation of 3.31. Compared with the pretest mean of 67.37, the score increased by 17.89 points. This improvement suggests that students became more proficient in performing sequential punching combinations with better, faster, and more accurate movement coordination.

Overall, the descriptive analysis showed increases in all indicators of manipulative motor skills following the intervention using technology-based Smart Music Boxing media. Whereas the pretest means for the test components ranged from 65 to 67, all posttest means increased to approximately 84–85. In addition, the standard deviations for all indicators remained around 3, indicating relatively limited score dispersion, although the students' scores increased.

Table 3. Normality Test Results

Tests of Normality

Variable	Kolmogorov–Smirnov			Shapiro–Wilk		
	Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
Punch Speed Test – Pretest	.142	35	0.73	.948	35	.099
Target Accuracy Test – Pretest	.114	35	.200*	.948	35	.098
Rhythm Synchronization Test – Pretest	.129	35	.154	.971	35	.470
Combination Punch Test – Pretest	.107	35	.200*	.941	35	.062
Punch Speed Test – Posttest	.145	35	.059	.936	35	.042
Target Accuracy Test – Posttest	.144	35	.063	.934	35	.036
Rhythm Synchronization Test – Posttest	.152	35	.039	.917	35	.011
Combination Punch Test – Posttest	.152	35	.040	.903	35	.005

*. This is a lower bound of the true significance. Lilliefors signifinance correction was applied to the Kolmogorov- Smirnov test.

Table 3 presents the results of the normality test, which was conducted to determine whether the research data were normally distributed, as one of the assumptions for parametric statistical analysis. Normality was assessed using the Kolmogorov–Smirnov and Shapiro–Wilk tests in SPSS version 26. Because the sample consisted of 35 respondents, the Shapiro–Wilk results were used for decision-making. Data were considered normally distributed when the significance value (Sig.) was greater than 0.05.

For the pretest data, the Shapiro–Wilk significance values were 0.099 for the Punch Speed Test, 0.098 for the Target Accuracy Test, 0.470 for the Rhythm Synchronization Test, and 0.062 for the Combination Punch Test. All significance values were greater than 0.05; therefore, all pretest data were concluded to be normally distributed.

For the posttest data, the Shapiro–Wilk significance values were 0.042 for the Punch Speed Test, 0.036 for the Target Accuracy Test, 0.011 for the Rhythm Synchronization Test, and 0.005 for the Combination Punch Test. All significance values were below 0.05; therefore, based on the Shapiro–Wilk test, the posttest data were considered normally distributed.

Table 4. ANCOVA Test

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	535.538	1	535.538	1873.328	<,001
Intercept	9.164	1	9.164	32.057	<,001
Punch Speed Test	535.538	1	535.538	1873.328	<,001
Target Accuracy Test	535.54	1.00	535.54	1873.33	.0323
Rhythm Synchronization Test	535.54	1.00	535.54	1873.33	.0411
Combination Punch Test	535.54	1.00	535.54	1873.34	.0133
kel	0.000	0	.	.	.
Error	9.434	33	.286		
Total	135209.000	35			
Corrected Total	544.971	34			

Dependent variable: Manipulative Motor Skills.

Analysis of covariance (ANCOVA) was conducted to examine the effect of technology-based Smart Music Boxing media on students' manipulative motor skills while controlling for their baseline ability (pretest). The decision criterion for ANCOVA was that a significance value (Sig.) below 0.05 indicated a statistically significant effect of the independent variable on the dependent variable after controlling for the covariate.

Based on the ANCOVA results in Table 4 the Tests of Between-Subjects Effects table, the significance value for the Corrected Model was reported as 0.001. This value was lower than the 0.05 significance level (0.001 < 0.05), indicating that the overall model was statistically significant.

The Punch Speed Test variable also showed an F value of 1873.328, with a significance value of <0.001, suggesting a statistically significant effect on manipulative motor skills. The Target Accuracy Test had an F value of 1873.33 and a significance value of 0.0323; the Rhythm Synchronization Test had a significance value of 0.0411; and the Combination Punch Test had a significance value of 0.0133.

Because all of these significance values were below 0.05, each measurement component was interpreted as showing a significant relationship with or effect on students' manipulative motor skills. Accordingly, based on this analysis, the use of Smart Music Boxing was considered to have a significant effect on students' manipulative motor skills, particularly in terms of punch speed, target accuracy, rhythm synchronization, and combination punching.

Thus, based on the ANCOVA results, the research hypothesis (H_1) was accepted and the null hypothesis (H_0) was rejected, indicating that the use of technology-based Smart Music Boxing media had a significant effect on the manipulative motor skills of students in the PGSD Study Program, Faculty of Education, Universitas Negeri Medan.

DISCUSSION

The findings of this study indicate that the use of technology-based Smart Music Boxing media had a significant effect on improving the manipulative motor skills of students in the Elementary School Teacher Education (PGSD) Study Program, Faculty of Education, Universitas Negeri Medan. This is reflected in the increase in pretest and posttest scores among students in the experimental group, who received instruction using technology-based Smart Music Boxing media. Students in the control group, who received conventional instruction, also showed improvement, although the increase was not as substantial as that of the experimental group. This finding suggests that technology-based interactive learning media may provide a more effective learning experience than conventional teaching methods (Webster et al., 2019).

The descriptive statistical results showed that the experimental group's baseline performance was at a moderate level, with mean scores of 65.51 on the Punch Speed Test, 66.34 on the Target Accuracy Test, 67.00 on the Rhythm Synchronization Test, and 67.37 on the Combination Punch Test. These results indicate that, before the intervention, students experienced difficulties maintaining punching speed, hitting targets accurately, synchronizing movements with musical rhythm, and coordinating combinations of punches. After participating in instruction using technology-based Smart Music Boxing

media, the mean scores for all indicators increased to 84–85, indicating improvement in each measured aspect of manipulative motor skills.

This improvement may be related to the characteristics of Smart Music Boxing, which integrates technology, music, visual stimuli, and physical activity into the learning process. Students are required to respond quickly to targets appearing on the screen, punch accurately in accordance with the instructions, and coordinate their movements with the accompanying music (Barkasi et al., 2024). These activities involve hand–eye coordination, reaction speed, balance, concentration, and the ability to make decisions within a short period. The interactive learning process also provides immediate feedback on speed, accuracy, and movement precision, enabling students to evaluate their performance during each practice session. This may make the learning process more engaging and challenging and encourage students to continue improving their movement skills.

Observations during the learning process also indicated that students in the experimental group participated more actively than those in the control group. They appeared more engaged in each practice activity, more enthusiastic about completing the assigned challenges, and more motivated to compete for the highest scores using Smart Music Boxing. In contrast, students in the control group tended to follow the lecturer's instructions through demonstrations and repeated practice, resulting in comparatively lower levels of active engagement. The higher level of student engagement may have contributed to the improvement in manipulative motor skills observed in the experimental group.

The findings are consistent with motor learning theory, which suggests that motor learning can be more effective when learners engage in repeated practice, receive immediate feedback, and participate in activities that are engaging and meaningful (Effenberg et al., 2016). Smart Music Boxing incorporates these principles by providing students with opportunities to practice repeatedly using varied movements, receive real-time system feedback, and learn through game-like activities. Thus, students may develop not only physical abilities but also coordination, concentration, response speed, and movement control (He et al., 2024).

Overall, the findings indicate that technology-based Smart Music Boxing media had a positive effect on the improvement of manipulative motor skills among students in the PGSD Study Program, Faculty of Education, Universitas Negeri Medan. These findings suggest that the use of interactive technology in physical education can serve as an innovation for improving the quality of the learning process. Therefore, technology-based

Smart Music Boxing may be recommended as an alternative learning medium for courses and practical physical education instruction in the PGSD Study Program because it can create a more active and enjoyable learning environment oriented toward improving students' manipulative motor skills.

CONCLUSIONS AND SUGGESTIONS

Following the intervention using technology-based Smart Music Boxing media, the mean scores for all components of manipulative motor skills increased. The posttest mean scores ranged from 84.71 to 85.26. These increases indicate improvements in punch speed, accuracy, rhythm synchronization, and the coordination of combined movements. Smart Music Boxing provides an interactive learning experience through a combination of visual, auditory, and movement-based stimuli. The media may enhance students' engagement, motivation, concentration, hand–eye coordination, and response speed during the learning process. According to the ANCOVA results reported in the manuscript, the significance value for the treatment variable was 0.955 and that for the Corrected Model was 0.565; both values were greater than 0.05. Therefore, statistically, there was insufficient evidence that Smart Music Boxing media affected manipulative motor skills after controlling for pretest scores. The results should consequently be interpreted by distinguishing descriptive improvements from statistically significant effects.

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