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Integrating basketball skills learning into mathematics: an innovative model to improve skills and performance

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ABSTRACT

Basketball skills learning has focused more on physical and technical aspects without considering quantitative analysis-based approaches such as mathematics, which can provide a deeper understanding of movement strategies and effectiveness. This study aimed to develop and test the effectiveness of a mathematics-based basketball skills learning model to improve students' understanding of movement concepts and playing performance. It used a research and development (R&D) method with a quasi-experimental approach, involving students as research subjects and measuring the model's effectiveness through validity tests, practicality, and improvement of student skills before and after implementing the model. The results of the effectiveness test of the learning model through pretest and posttest showed increased skills in three main aspects: dribbling, passing, and shooting. In dribbling skills, the percentage of achievement increased from 12.84% in the pretest to 20.86% in the posttest. Passing experienced a substantial increase from 27.26% to 41.92%, while shooting also increased from 4.11% to 9.11%. These results indicate that the applied math-based learning model improves students' basic basketball skills. Developing a mathematics-based learning model in basketball positively contributes to the effectiveness of sports skills learning, so it is recommended to be applied in the physical education curriculum to improve students' cognitive understanding and motor skills.

KEYWORDS

Basketball; Mathematics-Based Learning; Physical Education Innovation; Sports Learning Strategies

1. INTRODUCTION

Basketball is not only a physical activity but also has a close relationship with various disciplines, one of which is mathematics, which can be used to improve understanding of game strategy and technical skills. Studies (Ramulu et al., 2024a) mathematical concepts such as algebra, geometry, probability, and statistics are critical in sports analysis, improving strategy, performance, and decision-making, especially in basketball, spatial tracking data combined with game-by-game information can be analyzed to evaluate game strategy and player role (Manisera et al., 2019). Monte Carlo simulations can be applied to optimize shooting strategies, considering factors such as launch speed, angle, and player position (Min, 2016). This mathematical approach improves understanding of game dynamics and has potential educational benefits, fostering analytical skills, problem-solving, and critical thinking when integrated into mathematics instruction (Ramulu et al., 2024a).

Research shows that mathematics and basketball are closely related, offering opportunities to improve athletic performance and educational outcomes. Sports analytics can improve on-field performance while increasing student engagement in STEM subjects (Drazan et al., 2017). Mathematical concepts such as algebra, geometry, probability, and statistics are critical to optimizing strategy and decision-making in various sports, including basketball (Ramulu et al., 2024a). Basketball drills provide more excellent engagement opportunities than traditional math classes, potentially impacting student identity and learning experiences (Nasir & Hand, 2008). Advanced statistical methods and spatial tracking data analysis can be used to evaluate game strategies, player roles, and team performance in basketball (Manisera et al., 2019). Integrating math in basketball drills: A study found that combining basketball with math in physical education led to a 1424% increase in perceived autonomy and a 1609% increase in intrinsic motivation for math among children (Wienecke et al., 2021). Mathematical concepts such as geometry, probability, and statistics are essential for developing strategies and improving performance in basketball (Ramulu et al., 2024b). Athlete intelligence quotient (AIQ) cognitive development and performance have been shown to correlate with performance metrics in the NBA, suggesting that cognitive skills, which can be improved through math training, are critical to success in basketball (Hogan et al., 2023). Biomechanical research emphasizes the importance of integrating cognitive and physical training to ensure that athletes develop holistically (Hu & Huang, 2025)

In basketball skills, shooting angle, shooting speed, and player movement patterns can be mathematically analyzed to optimize technique and game effectiveness. Mathematical analysis of basketball shooting techniques reveals key factors to optimize performance. Studies have examined the kinematics of free throws and three-point shots, focusing on parameters such as shooting angle, speed, and player height (Simona et al., 2017;Veljović et al., 2021). Studies have shown that the optimal release angle is inversely proportional to the player's height, while the initial velocity and time to reach maximum ball height are directly related to the player's height (Nor-Al-Din et al., 2021) For three-point shots, shooting height, speed, and angle are positively correlated with the angle of entry of the ball into the basket (Veljović et al., 2021). Analysis of movement patterns using advanced techniques such as Dynamically Controlled Networks (DyCoN) has revealed individual characteristics and skill level differences in shooting patterns (Schmidt, 2012).

The basketball skills learning methods commonly used in schools and sports academies still tend to be conventional, lacking integration of quantitative analysis-based approaches such as mathematics, which can improve students' understanding in greater depth. A learning approach that combines mathematical concepts in mastering basketball skills can be an innovative solution that is more effective in improving the quality of students' understanding and performance.

Most research on basketball skill learning still focuses on the physical and technical aspects without exploring how the integration of mathematical concepts can contribute to improving playing skills. Recent research has explored innovative approaches to improving basketball skills beyond traditional physical and technical training. Integrating life skills into basketball training can significantly improve shooting accuracy and technique (Prasetyo et al., 2024). Shooting accuracy and technique significantly (Prasetyo et al., 2024). Similarly, incorporating mathematical concepts through physical activity, such as using Eduball in physical education classes, has been shown to stimulate the acquisition of mathematical knowledge and skills in elementary school students (Cichy et al., 2020). Basketball practice can provide opportunities for deep engagement, self-expression, and identity development, which may not always be available in a traditional classroom setting (Nasir & Hand, 2008). Furthermore, sport-specific knowledge is closely related to decision-making skills in basketball, while motor skills such as dribbling and shooting are related to control and execution components. These findings suggest that a more holistic approach to basketball practice, incorporating cognitive and life skills, may improve performance and overall development.

Several recent studies have shown that STEM (Science, Technology, Engineering, Mathematics) based approaches in sports have great potential to improve players' tactical and technical understanding but have not been widely applied in systematic basketball skills learning. The novelty of this study offers a new approach to basketball skills learning by developing a mathematical-based model to optimize students' understanding of the concept of movement and game strategy. This study aims to design, develop, and test the effectiveness of a mathematics-based basketball skills learning model in improving students' playing skills. Given the importance of innovation in sports learning methods, this study is highly urgent in contributing to physical education and providing a new perspective in a quantitative analysis-based sports learning approach.

2. METHODS

2.1. Study Design and Participants

This study uses a research and development (R&D) method with a quasi-experimental (Kim & Manquian, 2023), design with control and experimental groups, approach to test the effectiveness of a mathematics-based basketball skills learning model. This study was conducted at SMA Negeri 18 Pekanbaru, including a school environment with a basketball learning program.

This study's population was students taking basketball lessons at the high school level. The research sample was selected using a purposive sampling technique, which considered the active involvement of students in basketball learning and the readiness of students to participate in the experiment, totaling 34 people. A total of 34 high school students were randomly divided into two groups (n = 17). The instruments used in this study included a basketball skill test, a questionnaire on understanding mathematical concepts in the game, and observations during the learning process to evaluate the effectiveness of the developed model. The validity and reliability of the instruments were tested before being used in data collection.

2.2. Procedures

The research was conducted in several stages, namely 1) needs analysis and literature study, 2) development of a mathematics-based basketball skills learning model, 3) initial trial on a small scale, 4) implementation on a larger scale with a quasi-experimental design, and 5) evaluation of implementation results using effectiveness tests and feedback from participants.

2.3. Instruments

The basketball playing skills test uses the Johnson Basket Ball Test (1934), which has been revalidated by (Smith, 2020) with a reliability of 0.89 and a validity of 0.85. The intervention in the form of integrating mathematics learning (geometry and measurement concepts) into basic basketball technique training was carried out for 12 sessions. This test can be done for all ages and genders. This test includes: 1) shooting the ball into the basket. 2) throwing the ball into the wall, and 3) dribbling. The test was carried out once per test. The shooting test results are recorded according to the ball entering the basketball ring for 30 seconds, passing throws for 30 seconds to the wall, and dribbling results recorded by running while dribbling past the cone for 30 seconds.

2.4. Statistical Analyses

The data obtained were analyzed using statistical techniques by conducting validity tests, practicality tests, and t-tests to compare the increase in abilities before and after applying the learning model (V.I.O., 2024) and then continued with a test of the effectiveness of integrative learning on improving basketball skills, by comparing the pretest and posttest values in the control and experimental groups through n-Gain analysis and effect size (Cohen's d). This test aims to assess the extent to which the treatment (integration of mathematics learning into basketball training) has an impact on improving dribbling, passing, and shooting skills. The n-Gain value shows the percentage increase in skills from the pretest to the posttest, categorized in effectiveness levels (e.g., high and medium). At the same time, Cohen's d is used to measure the strength of the intervention effect between groups. Data analysis was carried out using a two-way t-test with the help of SPSS version 22.

3. RESULTS

The validation results from linguists indicate that the language quality in this study meets good standards. Based on Table 1, four aspects were assessed: language clarity (80%), readability (87%), accuracy (80%), and consistency (87%). The overall average score of 82% falls into the valid category, confirming that the linguistic aspects meet eligibility standards. The following table presents the validation details.

Table 1. Language expert validation

Linguist Aspect	Percentage Value	Description
Language Clarity	80%	Valid
Readability	87%	Valid
Language Accuracy	80%	Valid
Language Consistency	87%	Valid
Average	82%	Valid

Based on the results of the learning model expert validation in Table 2, the developed model was declared valid with an average score of 87%. The four main aspects assessed include model construction (80%), effectiveness (88%), applicability (92%), and attractiveness (88%). The applicability of the model obtained the highest score, indicating the ease of application in learning.

Thus, this model is considered feasible and effective for use in the educational process. The following table is below:

Table 2. Learning model experts

Learning Model Expert Aspects	Percentage Value	Description
Learning Model construction	80%	Valid
Model Effectiveness	88%	Valid
Model Implementability	92%	Valid
Model Attractiveness	88%	Valid
Average	87%	Valid

The validation results by geometry experts in Table 3 indicate a high level of validity, with an average score of 87%. All assessed aspects scored at least 80%, meeting curriculum standards, visualization use, teaching creativity, and interdisciplinary integration. Notably, discovery-based learning, tool utilization, cross-disciplinary integration, teacher guidance, and evaluation coverage scored 100%. Thus, the model is valid and ready for application in geometry learning. The following table presents the details.

Table 3. Geometry expert

Learning Model Expert Aspects	Percentage Value	Description
Suitability of the material to the curriculum and learning standards.	80%	Valid
Utilization of visualizations such as diagrams, graphs, and models.	80%	Valid
Innovative use of digital tools and interactive media.	80%	Valid
Creativity of teaching methods and student engagement in the learning process.	80%	Valid
Differentiation of approaches and adaptation of methods according to student characteristics.	80%	Valid
Discovery-based learning approach and student involvement in experiments.	100%	Valid
Understanding and application of basic theorems in problem solving.	80%	Valid
Relevance of real applications and contextualization of geometry concepts.	80%	Valid
Use of periodic evaluation and provision of constructive feedback.	80%	Valid
Availability and utilization of teaching aids that support concept visualization.	100%	Valid
Integration with other disciplines and application of knowledge across fields.	100%	Valid
Project-based and case study approaches to hone problem solving skills.	80%	Valid
Development of analytical skills and the ability to	80%	Valid

critically evaluate.		
Teacher skills in guiding, directing and creating a conducive learning atmosphere.	100%	Valid
Comprehensive evaluation coverage that measures aspects of students' knowledge, attitudes and practical skills.	100%	Valid
Rata-Rata	87%	Valid

The validation results by basketball experts in Table 4 indicate a high level of validity, with an average score of 91%. Several aspects, including the completeness of basic techniques, innovative methods, supporting media quality, skill evaluation, material differentiation, technology utilization, and psychological integration, scored 100%. Other aspects, such as technical and physical balance, tactical application, and sportsmanship values, scored 80%, maintaining validity. Thus, the model is deemed feasible and effective for basketball learning. The following table presents the details:

Table 4. Basketball expert

Basketball Expert Aspects	Percentage Score	Description
Content conformity with national/regional curriculum and competency standards.	80%	Valid
Completeness and depth of presentation of basic techniques.	100%	Valid
Balance between techniques and physical aspects in learning.	80%	Valid
Explanation of tactics, formations, and game strategies that are applicable.	80%	Valid
Use of innovative methods such as simulation, role play, and match video analysis.	100%	Valid
Availability and quality of supporting media for basketball learning.	100%	Valid
Clarity of delivery, use of communicative language, and variety of presentation methods.	80%	Valid
Integration of sportsmanship, fair play, and cooperation values in learning activities.	80%	Valid
Presentation of safety standards, warm-up techniques, and injury prevention.	80%	Valid
Clarity of evaluation methods, such as skill tests, observation, and feedback from the coach.	100%	Valid
Differentiation in the presentation of materials and exercises according to the ability level of the students.	100%	Valid
Utilization of technology for analysis of techniques and strategies during games.	80%	Valid
Encouragement of innovation and freedom to develop their own style of play.	100%	Valid
Integration of psychological techniques to improve	100%	Valid

concentration, enthusiasm, and confidence.		
Congruence between learning objectives and competency achievement in training and matches.	100%	Valid
Rata-Rata	91%	Valid

The teachers' responses in Table 5 indicate a high level of practicality for the learning model, with an achievement level of 80.65%, categorized as "Practical." Among 102 respondents, 55.53% agreed, 35.29% strongly agreed, and only 9.18% were doubtful, with no disagreement recorded.

Table 5. Practicality of user response (teacher)

No	Scale	Value	Number of Answers	Total Score	Frequency	Achievement Level	Category
1	Strongly Agree	5	30	150	35.29%	80.65%	Practical
2	Agree	4	59	236	55.53%		
3	Doubtful	3	13	39	9.18%		
4	Don't Agree	2	0	0	0%		
5	Strongly Disagree	1	0	0	0%		
Total			102	425	100%		

Similarly, Table 6 shows that 65.90% of teachers agreed, 32.30% strongly agreed, and only 1.80% were doubtful, resulting in a total score 425. These findings confirm that the learning model is practical and feasible for effective implementation. The following table and graph present the details.

Table 6. Practicality interval of user response (teacher)

Interval	Answer	Persentation
Strongly Agree	150	32.30%
Agree	236	65.90%
Doubtful	39	1.80%
Don't Agree	0	0%
Strongly Disagree	0	0%
Total	**425**	**100%**

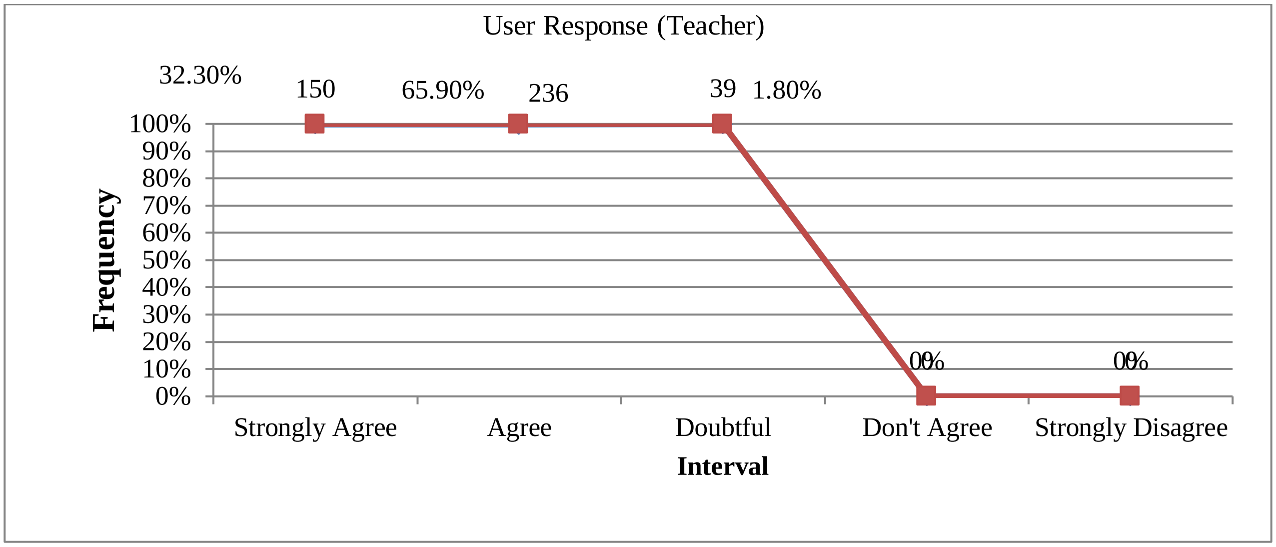

Figure 1. User response graph (teacher)

Based on Table 7, students' responses indicate a high level of practicality for the learning model, with an achievement level of 81.74%, categorized as "Practical." 53.22% of students stated "Strongly Agree," while 46.78% stated "Agree," with no hesitation or disagreement.

Table 7. Practicality of user response (students)

No	Scale	Value	Number of Answers	Total Score	Frequency	Achievement Level	Category
1	Strongly Agree	5	243	1215	53.22%	81.74%	Practical
2	Agree	4	267	1068	46.78%		
3	Doubtful	3	0	0	0%		
4	Don't Agree	2	0	0	0%		
5	Strongly Disagree	1	0	0	0%		
	Total		510	2283	100%		

Similarly, Table 8 and Figure 2 show unanimous positive responses, with the same percentage distribution and a total score of 2283.

Table 8. Practicality interval of user response (students)

Interval	Answers	Persentation
Strongly Agree	1215	53.22%
Agree	1068	46.78%
Doubtful	0	0%
Don't Agree	0	0%
Strongly Disagree	0	0%
Total	2283	100%

These results confirm that students will receive a practical learning model for effective implementation.

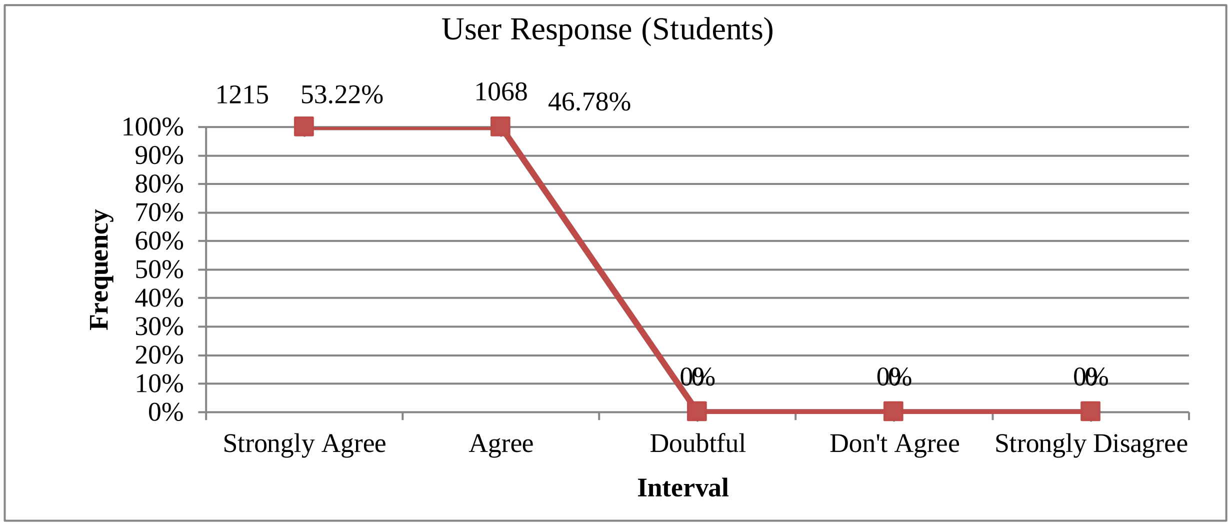

Figure 2. Graph of user response (students)

In the following, based on Table 9, the results show that integrating mathematics learning into basketball skills training positively impacted students' skills, especially in the aspects of dribbling, passing, and shooting. In dribbling skills, the experimental group experienced an increase from an average pretest score of 12.84% to 20.86% in the posttest, with an n-Gain value of 15.85%, which is classified as a high increase category. In contrast, the control group only showed an increase from 15.20% to 25.16%, with an n-Gain of 9.20%, also in the high category. However, the effect size (Cohen's d) of 14.19 indicates that the treatment given to the experimental group significantly improved dribbling skills.

Table 9. Comparison of basketball skill improvement and effect size

Skill Test Form	Control		Ngain %	Description	Experimental		Ngain %	Description	Cohen's
	Pretest	Postest			Pretest	Postest			
Dribbling	15.20%	25.16%	9.20%	Hight	12.84 %	20.86 %	15.85%	Hight	14.19
Passing	23.76%	37.20%	19,76%	Hight	27.26 %	41.92 %	38.80%	Hight	3.02
Shooting	2.11%	3.85%	4.01%	Hight	4.11%	9.11%	5.58%	Medium	7.28

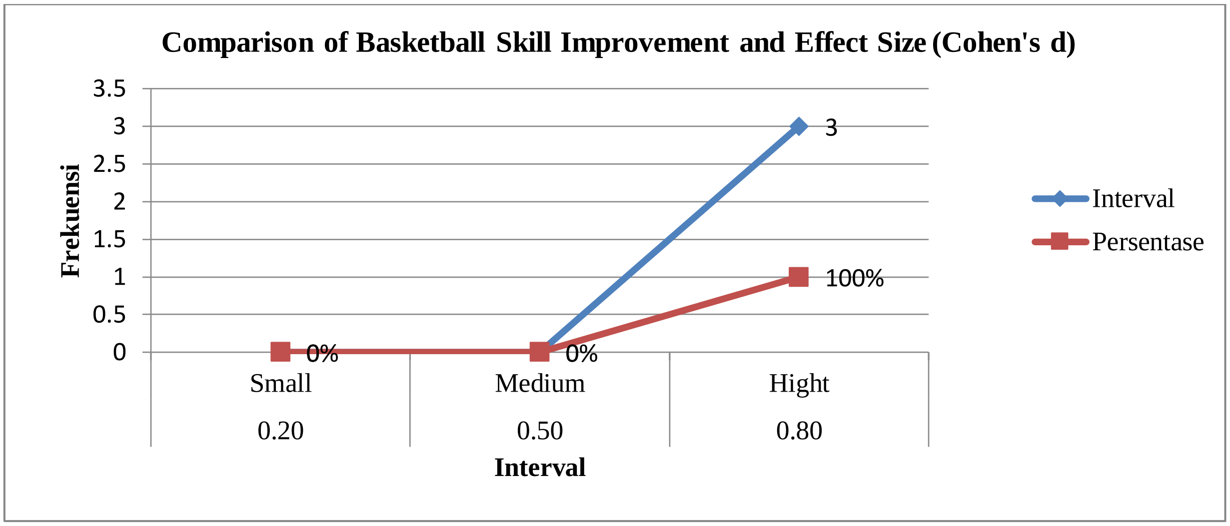

Figure 3. Comparison of basketball skill improvement and effect size

In the passing aspect, the experimental group recorded an increase from 27.26% to 41.92%, with an n-Gain of 38.80% (high category). The control group also showed an increase from 23.76% to 37.20%, with an n-Gain of 19.76%, also in the high category. Although both groups experienced an increase, the experimental group showed a more significant spike. Cohen's d value of 3.02 strengthens this finding, indicating that the innovative treatment significantly affected the mastery of passing skills. Meanwhile, for shooting skills, the experimental group increased from 4.11% to 9.11%, with an n-Gain of 5.58% (moderate category). The control group increased from 2.11% to 3.85%, with an n-Gain of 4.01%, still in the high category. Although the increase in this aspect is not as significant as the other aspects, Cohen's d value of 7.28 still shows that the effect of the treatment on shooting improvement is quite strong. Overall, these findings indicate that the integrative learning model is not only relevant in the context of physical education but is also able to create productive synergy between academic mastery (mathematics) and motor skills (basketball), thus providing an innovative learning alternative that has a real impact on student performance.

4. DISCUSSION

Implementing a mathematics-based basketball skills learning model has significantly impacted students' understanding of movement concepts and their playing skills. This approach integrates mathematical principles into basketball training, improving tactical understanding and skill execution. Students showed improved basketball skills, as evidenced by higher post-test scores than pre-test scores, indicating effective learning outcomes (Kurniadi et al., 2023). Integrating technology and mathematics in basketball education fosters physical skills and cognitive abilities, such as strategy and analysis (Kurniadi et al., 2023). Using game-based learning strategies has significantly improved academic performance, which can be paralleled in sports education, where tactical understanding is essential (Cayang & Ursabia, 2024). The Tactical Game approach in basketball has been shown to improve decision-making and execution skills among students, further supporting the development of tactical understanding (González-Espinosa et al., 2021).

Recent studies have explored innovative approaches to integrating mathematics with physical activities, particularly basketball, to enhance learning and motivation. These approaches align with enactivist mathematics pedagogy, which emphasizes thinking as situated doing and learning through perception and reflection on physical activities (Abrahamson et al., 2022). The importance of revealing mathematical activity in non-formal learning spaces is highlighted by a framework connecting research on number systems, embodied cognition, and emergent mathematical activity in making spaces (Williams et al., 2024). These studies demonstrate the potential of integrating mathematics with physical activities to create engaging, effective learning experiences that bridge formal and informal educational contexts.

Basketball provides an engaging context for teaching physics and mathematics concepts. Studies have explored the physics of basketball shots, including optimal shooting angles and energy efficiency (Zhang et al., 2023). For mid-range shots (3-5 meters), the optimal angle is 55-51 degrees, while for three-point shots, it's 49-47 degrees (Zhang et al., 2023). Mathematical models using multiple regression analysis have been developed to analyze shooting percentages and determine optimal shooting speeds (Liu & Liu, 2023). These principles can be applied in classroom settings, where students can use high-speed cameras and video analysis tools to study projectile motion and kinematics graphs (Paosawatyanyong & Wattanakasiwich, 2010). By incorporating real-world basketball scenarios, educators can help students better understand complex physics concepts and improve their graph interpretation skills (Paosawatyanyong & Wattanakasiwich, 2010). This approach demonstrates the potential for integrating sports into STEM education to enhance student engagement and learning outcomes. In contrast, while the integration of mathematics into sports like basketball is beneficial, some educators may argue that focusing too heavily on mathematical concepts could detract from the physical enjoyment and skills development inherent in the sport itself. Balancing these elements is crucial for a holistic educational approach (Stylianou et al., 2013).

The effectiveness of cognitive-based learning models in sports can be understood by integrating motor learning theory and motion analysis approaches. This framework emphasizes the importance of understanding mathematical principles such as angle, velocity, and momentum, which can improve the accuracy of athletes' movements. The following section outlines the main aspects of this relationship. Cognitive training techniques, such as motor imagery, facilitate skill acquisition by allowing athletes to mentally simulate movements, which can lead to improved performance outcomes (Lindsay et al., 2023). Nonlinear pedagogy encourages learners to explore movement solutions that align with their constraints, promoting performance adaptability (Lindsay et al., 2023). Research in elite springboard diving highlights the importance of adapting movement patterns to varying conditions, showing that athletes can achieve consistent performance despite suboptimal takeoffs (Barris, 2013). Gesture recognition systems leverage data analytics to provide real-time feedback, improving training efficiency and safety by allowing athletes to refine their technique based on precise movement data (Mohamed et al., 2024). Integrating virtual reality technology into sports training has improved motion capture accuracy, allowing for better understanding and executing complex movement (Pan, 2024). Understanding movement dynamics, such as representational momentum, helps athletes anticipate movement, improving their performance in dynamic sports contexts (Rodrigues & Teixeira, 2024). Athletes' motor imagery can mentally simulate movements, which has been shown to improve skill acquisition and performance outcomes (Frank et al., 2024). Advanced movement analysis using deep learning enhances athletes' movement recognition, integrating biological mechanisms to improve performance feedback (Zhang et al., 2025). A functional approach to movement analysis focuses on task accomplishment rather than idealized movements, allowing customized training interventions (Hossner et al., 2015).

Integrating technology and interactive media into the physical education (PE) curriculum presents a promising opportunity to enhance students' understanding of mathematical concepts in sports. Integrating technology into physical education (PE) offers an innovative approach to enhance student engagement and learning outcomes. The Math & Movement program incorporates kinesthetic activities to practice mathematical concepts in the PE curriculum (Wade, 2016). Wearable devices and virtual reality applications provide real-time data collection, performance feedback, and immersive learning experiences (Singh & Awasthi, 2024). Integrating technology and interactive media into the physical education (PE) curriculum presents a promising opportunity to enhance students' understanding of mathematical concepts in sports. Integrating technology into physical education (PE) offers an innovative approach to enhance student engagement and learning outcomes. The Math & Movement program incorporates kinesthetic activities to practice mathematical concepts in the PE curriculum (Wade, 2016). Wearable devices and virtual reality applications provide real-time data collection, performance feedback, and immersive learning experiences (Singh & Awasthi, 2024).

Benefits of Integrating Technology in PE Enhanced learning outcomes, with studies showing that interactive models, such as those based on computer platforms, improve self-efficacy and learning outcomes in physical education (Qian & Kim, 2025). Personalized Education: Machine learning algorithms can analyze student data to recommend customized PE courses, increasing participation and satisfaction (Song et al., 2024). Multimedia engagement with multimedia devices in PE can bridge the gap between traditional teaching methods and modern educational needs, making learning more dynamic (Li & Lu, 2019). Self-efficacy-enhancing technologies, including wearable fitness trackers and interactive apps, increase students' confidence in their physical abilities (Anthony, 2024; Gong et al., 2024) Personalized training machine learning algorithms analyze student data to create customized PE courses, leading to higher participation and satisfaction (Lu, 2024; Zhaori; Getu & Li, 2024). Dynamic learning involving multimedia The use of multimedia devices bridges traditional teaching methods with modern educational needs, making PE classes more engaging (Zhang & Liu, 2024). Technologies such as motion capture provide immediate feedback, allowing students to correct their form and improve their performance (ZhaoriGetu & Li, 2024). While technology integration in PE presents significant advantages, challenges such as resource limitations and teacher training must be addressed to fully realize its potential in enhancing educational experiences. Although technology integration in PE shows excellent potential, it is important to consider implementation challenges, such as teacher training needs and resource allocation, which may hinder widespread adoption. This study has limitations in terms of sample size, which is still limited and has not tested the effectiveness of the model in the long term, so further research is needed with a broader scope and variation in student skill levels.

Several teachers reported that this integrative approach helped motivate students and made mathematics lessons more contextual and enjoyable. On the other hand, students reported that they found it easier to understand abstract mathematical concepts because they were linked to real and meaningful physical activities. These testimonies highlight that the model improves learning outcomes quantitatively, provides a more holistic learning experience, and touches on students' affective dimensions. Thus, including qualitative data adds depth to interpreting the results and strengthens the claim of the model's practicality and relevance in real-world learning contexts. The combination of quantitative and qualitative approaches (mixed methods) makes the research more comprehensive and applicable within the framework of educational innovation.

Although the increase in shooting ability is relatively minor compared to the other two aspects, these results still show the effectiveness of the applied learning model. The presentation of data with rounding is adjusted to the relatively small sample size to describe more meaningful and realistic differences in the context of physical education. These findings indicate that the integration of mathematical concepts in basketball training can positively impact students' mastery of fundamental motor skills in a measurable and applicable manner.

Overall, these findings indicate that the integrative learning model is not only relevant in the context of physical education but is also able to create productive synergies between academic mastery (mathematics) and motor skills (basketball), thus providing an innovative learning alternative that has a real impact on student performance. Furthermore, although technology integration in PE shows great potential, it is important to consider implementation challenges, such as teacher training needs and resource allocation, which may hinder widespread adoption. This study has limitations in terms of sample size, which is still limited and has not tested the effectiveness of the model in the long term, so further research is needed with a broader scope and various levels of student skills.

5. CONCLUCIONS

This study successfully developed and tested the effectiveness of a mathematics-based basketball skills learning model in improving students' understanding of movement concepts and playing performance. Based on the pretest and posttest results, there was a significant increase in dribbling, passing, and shooting skills, indicating that this approach can integrate cognitive and motor aspects effectively. The implications of these findings indicate that physical education learning does not have to stand apart from academic domains such as mathematics. On the contrary, this cross-disciplinary approach can simultaneously increase student engagement, motivation, and learning outcomes in two domains. Therefore, this learning model is very feasible to be integrated into the design of the physical education curriculum as an innovative strategy to achieve more comprehensive learning. Teachers can use this model to design learning sessions that emphasize physical skills and involve measuring angles and speeds and analyzing playing strategies using mathematical concepts. Furthermore, this model can be expanded through technological support such as motion capture, wearable devices, and interactive learning applications that combine quantitative data with physical training. Thus, this mathematics-based learning model not only improves students' learning outcomes in basketball but also makes an important contribution to the 21st-century learning reform that demands integration between disciplines and the use of technology to improve the overall effectiveness of education.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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