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Original Article

Digital-based gymnastics learning tools: A design and implementation for undergraduate sports education students

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Abstract:
The role of technology in learning or improving a movement technique in sport has been investigated in previous studies. However, involving and developing it in gymnastics learning at universities is still rarely done. Therefore, the aim of this research is to develop and test the effectiveness of digital-based gymnastics learning tools for undergraduate sports education students. A total of 11 experts participated to assess the feasibility of the product, each of which was 5 gymnastics learning experts, 3 media and technology experts, and 3 language experts. Then, 64 undergraduate sports education students were involved in field trials. Participants consisted of experimental and conventional classes, or groups with developed products (n=33) and groups with conventional learning (n=31). A validation instrument with a Likert scale was used to determine the relevance of the content, and a back-rolling skills to test its effectiveness (initial, main and final phases). Then it was analyzed using the V index from Aiken and the Intraclass Correlation Coefficient (*ICC*), while the independent sample t-test and N-Gain score were used to analyze its effectiveness. These findings show that the V and *ICC* indices for e-learning plans and e-modules meet the feasibility indicators in the high category (V=0.812; 0.825 and *ICC*=0.736; 0.754). The results of the field trials also showed a significant difference between the experimental and conventional groups (P<0.05), where the average rear rolling skill in the experimental group was better than the conventional (8.82>7.55; difference 1.27), with N-Gain score analysis is 60.74 (moderately effective). Thus, this digital-based gymnastics learning tool can be used to overcome limitations in learning movements in gymnastics, whether used by students, lecturers and gymnastics practitioners. Future research is needed with more refined displays of products, and other movements in gymnastics.
Keywords: gymnastics, artistic, back rolling, sports technology, digital

Introduction

Artistic gymnastics is one of the lessons in the physical education curriculum and is a mandatory course for undergraduate sports education students (Zulbahri et al., 2022). Gymnastics skills requireupper body control while in the air (e.g. falling, twisting, flipping), and proper landing techniques to avoid injury (Desai et al., 2019). Basically, gymnasts perform a series of difficult and complex movements to perform acrobatics, which require high levels of strength, coordination and flexibility (French et al., 2004; Jemni et al., 2006). These physical components are also needed in various sports (Antara et al., 2023; Ihsan et al., 2022; Rifki et al., 2022). Therefore, the movements are very dependent on motor activity (a type of movement that depends on technique), the complexity of coordination exercises, and good stability (Nassib et al., 2020).

In this regard, a holistic approach in teaching needs to be applied evenly, such as motoric, emotional and cognitive aspects (Hsia et al., 2016). In this case, the role of digital technology in physical education has been investigated for these three aspects (Martin et al., 2015). It cannot be denied that the use of digital technology in learning continues to grow in various countries (Kretschmann, 2015; Roure et al., 2019; Sung et al., 2016), so that conventional learning has shifted to using the help of technology. Apart from that, digital-based gymnastics learning media is an effort to achieve effective and efficient learning goals in physical education (Handayani et al., 2023; Zulbahri et al., 2022). Studies from Legrain et al., that students involved in digital technology-assisted teaching will have a greater impact on perception and motivation compared to those involved in traditional teaching (Legrain et al., 2015). This study clearly reports the benefits of using digital technology when integrated

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with pedagogical approaches in physical education (Roure et al., 2019). Unfortunately, teaching gymnastics with the help of digital technology to undergraduate sports education students is still rarely done.

Technology is not fully exploited to impact teachers' pedagogical practices and positively influence student learning (Weir & Connor, 2015). This complex relationship shows that some teachers are enthusiastic about implementing technology in teaching, and there are also those who reject it. This is due to a lack of support or expertise to apply it in learning (Fullan, 2013; Palao et al., 2015). Thus, the use of digital technologies must be questioned from a pedagogical approach, and it is necessary to identify their potential to apply them in learning with clear benefits (Casey et al., 2017).

Various studies related to technology-assisted gymnastics learning have also been investigated, such as the use of video feedback on motor skills, self-assessment ability and motivation (Potdevin et al., 2018). This study involved beginner children learning gymnastics skills, they were divided into experimental and control groups, with the duration of treatment being 5 weeks. Study conducted by Le Naour et al. (2019), who assessed the efficacy of different types of visual information to improve the execution of roundoff movements in gymnastics. The study involved 32 participants aged 20 to 26 years, investigating two types of 3D feedback compared to 3D visualization. Study conducted by Roure et al. (2019), who investigated the effect of using video feedback on students' situational interest in gymnastics. This study involved 361 students aged 11 to 17 years, consisting of 4 secondary schools, practicing technical skills in gymnastics. Study conducted by Kokarev et al. (2023a), who proved the feasibility of using innovative tools, methods and techniques to increase technical readiness. The study involved 24 highly skilled athletes from the Ukrainian national aerobics team, aged 18 to 26 years. Study conducted by Zulbahri et al. (2022), who developed digital-based gymnastics learning media for undergraduate sports education students. This study aims to develop gymnastics learning media on rolling front round material. The experts and 45 undergraduate sports education students were involved in this study (15 students for small group trials and 30 for large group trials), but no treatment was provided in this study. Then, a study was conducted by Handayani et al. (2023), who developed and produced gymnastics learning media in physical education. This study focuses on handstand skills contained in products in the form of learning media using Android. This study involved experts and 47 junior high school students as an experimental class for its effectiveness, namely students who took part in gymnastics lessons in physical education classes. As far as we know, there are very few studies that develop products in the form of digital-based gymnastics learning tools for undergraduate sports education students, and how their effectiveness is compared between groups.

This research aims to develop and test the effectiveness of digital-based gymnastics learning tools for undergraduate sports education students. It is hoped that this product can overcome the limitations in studying movements in gymnastics, whether used by students, lecturers and gymnastics practitioners.

Methods

Design and participants

This research is *R&D*, which aims to develop digital-based gymnastics learning tools. A total of 11 experts participated in this study, each of which was 5 gymnastics learning experts, 3 media and technology experts, and 3 language experts. The experts are lecturers at the Faculty of Sports Science, Faculty of Educational Technology, and Faculty of Educational Sciences, Universitas Negeri Padang, Indonesia. Then, 64 sports education undergraduate students at Padang State University, Indonesia were involved in field trials. Participants consisted of two classes, namely the experimental class or group with digital-based gymnastics learning tools (*n*=33) and the control class or group that carried out conventional learning (*n*=31). Group selection was based on cluster random sampling, where students were in different classes and took gymnastics courses in the January-June 2022 semester.

Procedure

The procedures in developing this product refer to the Plomp & Nieven model, namely preliminary research, prototyping and assessment phase (Plomp & Nieveen, 2013). Preliminary research is the basis for developing digital-based gymnastics learning tools. This stage consists of needs and context analysis, namely analysis of the characteristics of gymnastics learning and students (such as analysis of gymnastics skills, technology-based learning, curriculum and gymnastics materials).

The prototyping phase aims to design digital-based gymnastics learning tools and the necessary instruments. The evaluation methods used for each prototype are: (a) Prototype one: After completion of the flow design, a self-evaluation is carried out which aims to check for errors in the design, so that appropriate and relevant product criteria are obtained (prototype one is revised before the prototype stage two); (b) Prototype two: This stage is validated by experts; (c) Prototype three: This stage is a formative evaluation for the entire series of phases. The final prototype will be used in actual conditions, so that the quality of digital-based learning tools is known for improving gymnastics skills in undergraduate sports education students.

Furthermore, the assessment phase is an assessment of the development of digital-based gymnastics learning tools that have been implemented (effectiveness). Effectiveness assessment is based on whether or not there is an increase in gymnastics skills from the product that has been developed. This effectiveness test involved undergraduate sports education students who took gymnastics courses. Students consist of experimental and control classes, or groups with developed products and groups with conventional learning.

Instruments

Expert validation instruments are used to obtain data from product assessments in the form of digital-based gymnastics learning tools. The aspects assessed are semester learning plans and e-modules (Table 1). Meanwhile, the effectiveness of digital-based gymnastics learning tools can be seen from the aspect of students' skills in performing back rolling movements, which include the initial, main and final phases. The implementation and assessment for each phase of this movement are presented in Figure 1 and Table 2.

a) b) c)

Figure 1. a) Implementation of round back rolling, b) straddle, and c) corner

Table 1. Assessment aspects for product feasibility

Aspects	Indicators	Sub indicators	Items
E-learning plans	Learning outcomes	- Learning outcomes are arranged in accordance with the sub-learning outcomes of the course and the expected abilities. - Learning objectives are formulated in good and correct language. - Learning objectives are formulated based on the cognitive level of students.	3
	Learning activities	- Activities are arranged in accordance with project-based learning. - Activities describe the stages of student thinking. - Activities are arranged to facilitate students in finding concepts. - Illustrations on activities can clarify in finding learning concepts. - The problems given can stimulate students' problem-solving abilities. - The drawings and illustrations used are in accordance with the material studied. - Activities are arranged using good and correct language.	7
	Learning materials	- The material is arranged describing the behavior that will appear in students. - The material is arranged describing the stage of thinking of students. - The material is arranged according to the expected ability. - The material is arranged according to learning activities. - The material is arranged using good and correct language.	5
E-modules	Didactic aspect	- Module alignment with learning outcomes and objectives. - Suitability of activities to the learning flow. - Activities designed can motivate students to construct their knowledge. - Learning activities can motivate students to ask questions. - Learning activities can guide students in finding concepts. - Helping lecturers to connect material to everyday problems. - Suitability of assessment instruments.	8
	Construction aspects	- Cover compliance with module identity. - Module overview, module usage, learning outcomes and objectives. - Contains components of learning activities. - Consistent in using terms and symbols. - The illustrations in the module can clarify the concept.	14
	Content aspect	- There are learning theories about gymnastics. - Load information about learning resources. - Contains the implementation of learning assignments on a project basis.	7

		- Suitability of topic with the demands of learning achievements and objectives. - Contains complete evaluation and assessment techniques.	
	Language aspect	- Conformity of the sentences used with good and correct Indonesian rules. - Use language that suits the student. - Use a clear sentence structure that does not cause confusion.	4
	Graphics	- Font shape and size. - Organized and neat layout. - Interesting colors. - Attractive look.	4

The assessment alternatives are 1 for invalid, 2 for less valid, 3 for moderately valid, 4 for valid, and 5 for very valid.

Table 2. Assessment aspects for effectiveness

Back rolling movement	Assessment			Score
	Initial phase	Main phase	Final phase	
Round back rolling	3	4	3	10
Straddle back rolling	3	4	3	10
Corner back rolling	3	4	3	10

The minimum score for each movement phase is 1, the maximum score is 3 (initial and final phases), and 4 for the main phase, the total and average score for each/all movement phases is 10.

Data analysis

Prototype testing from expert assessments was analyzed using Aiken's *V* index (Aiken, 1985) and *ICC* (Cho, 1981) (Table 3). Then, the effectiveness test was analyzed using an independent sample t-test, while N-Gain score analysis was used if there were differences in exercise skills between the experimental and conventional groups. The values obtained were interpreted according to the N-Gain score effectiveness interpretation category (Table 4).

Table 3. Categories for *V* index and *ICC*

V Index	Category	*ICC*	Category
$V > 0.8$	High	> 0.80	Very high
$0.4 \leq V \leq 0.8$	Moderate	0.61-0.80	High
$V < 0.4$	Low	0.41-0.60	Moderate
		< 0.41	Low

Table 4. Categories of interpretation of the effectiveness of the N-Gain Score

N-Gain score		Improved gymnastics skills	
Percentage	Category	N-Gain	Category
< 40	Ineffective	$g > 0.7$	High
40 – 55	less effective	$0.3 < g < 0.7$	Moderate
56 – 75	Moderately effective	$g < 0.3$	Low
>76	Effective		

Results

Product description

This digital-based gymnastics learning tool contains a menu of instructions for use, e-learning plans, gymnastics lecture materials, practice videos, and assignments which are packaged in an e-module.

The instructions menu contains an explanation of how to use e-learning plans and e-modules for undergraduate sports education students. The instructions menu also explains the features contained in e-learning plans and e-modules, such as course materials, pictures, practice videos and assignments.

The e-learning plan contains course identity, course descriptions, learning outcomes and course materials. It also contains a description or learning matrix that describes course material for one semester (meetings 1 to 16), where each week contains planned abilities, learning materials, learning methods or strategies, learning time, learning experiences, assessment techniques, value weights, and a list of references.

The course material contains explanations and theoretical material topics accompanied by pictures. This course material is arranged according to the order of material in the semester learning plan for gymnastics courses. The material created in the module is arranged from meetings 2 to 15. The material at each meeting contains an introduction, material presentation, summary and evaluation. The introductory section contains a brief description of the course, the relevance of the course and the expected learning outcomes. The presentation of the material contains an explanation of the material theoretically, accompanied by pictures and a summary.

Practice videos contain videos of the implementation of gymnastic movements that will be studied by students according to the semester learning plan at each meeting. Then, assignments in the e-module are prepared at each meeting (meetings 2 to 15). This assignment is structured in the form of a project, which contains instructions for the tasks that will be carried out by students. Figures 2.a to 5.a are the product design in prototype one, while Figures 2.b to 5.b are the revised final form of the product. The description of this product can be explored using the following link:

E-learning plan for gymnastics learning
Initial product : https://bit.ly/Produk_Awal_RPS_Senam_Dasar_ZULBAHRI
Revision product : https://bit.ly/Revisi_RPS_Senam_Dasar_ZULBAHRI
Final product : https://bit.ly/RPS_Senam_Dasar_Zulbahri_2022

E-module for gymnastics learning
Initial product : https://bit.ly/Produk_Awal_E-Modul_Mahasiswa_Senam_Dasar_ZULBAHRI
Revision product : https://bit.ly/Revisi_E-Modul_Mahasiswa_Senam_Dasar_ZULBAHRI
Final product : https://bit.ly/E-Modul_Mahasiswa_Senam_Dasar_ZULBAHRI

E-book as a guide for lecturers who teach gymnastics learning
Initial product : https://bit.ly/Produk_Awal_E-book_Dosen_Senam_Dasar_ZULBAHRI
Revision product : https://bit.ly/Revisi_E-book_Dosen_Senam_Dasar_ZULBAHRI
Final product : https://bit.ly/E-Book_Dosen_Senam_Dasar_Zulbahri

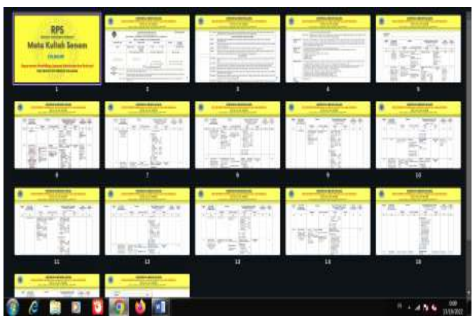
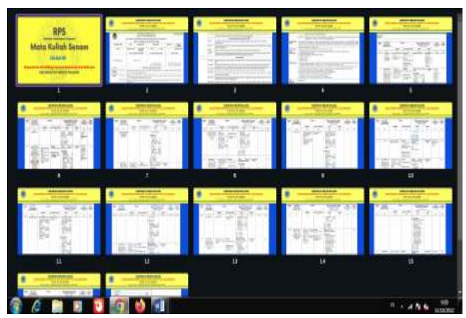
a)  b) 

Figure 2. a) Display of the e-learning plan before and b) after revision

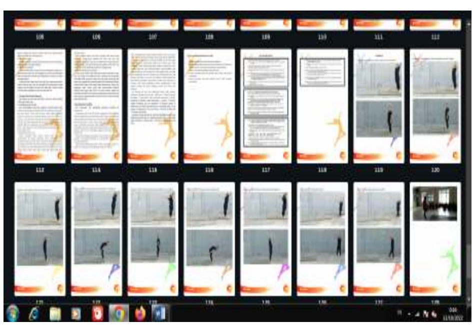
a)  b) 

Figure 3. a) Display of the e-module for students before and b) after revision

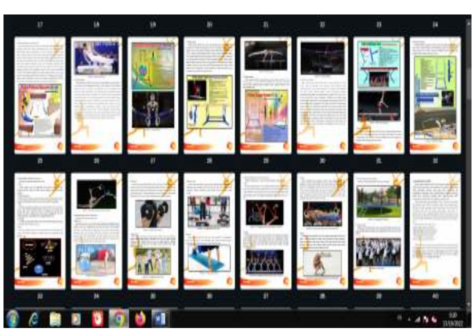
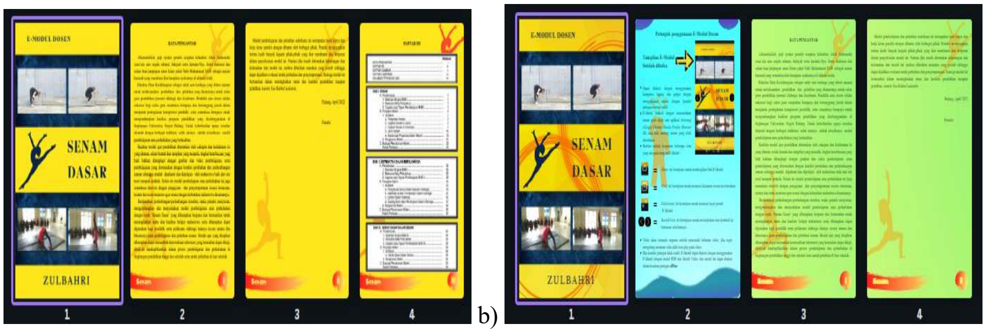
a)  b) 

Figure 4. a) Display of the e-module for lecturers before and b) after revision



a) b)
Figure 5. a) Background view before and b) after revision

Analysis of expert judgment

The validation results of this digital-based gymnastics learning tools were carried out on prototype two. Experts provide assessments and comments for improvement as a condition for meeting intervention quality criteria (content validity). As presented in Table 5, the *V* index and *ICC* values for e-learning plans was 0.812 and 0.736. Meanwhile for the e-module was 0.825 and 0.754. Comments from experts for product improvements are presented in Table 6. Then, the product after revision is presented in Figures 2.b to 5.b.

Table 5. Summary analysis of expert assessments

Aspects	Indicators	Index *V*	*ICC*
E-learning plans	Learning outcomes Learning activities Learning materials	0.812 ± 0.009 (high)	0.736 ± 0.034 (high)
E-modules	Didactic aspect Construction aspects Content aspect Language aspect Graphics	0.825 ± 0.039 (high)	0.754 ± 0.043 (high)

Table 6. Comments from experts

Expertise	Commentary
Gymnastics learning	- The semester learning plan and e-modules are basically well prepared (theory, pictures and videos). However, it is necessary to explain more about the use of terms in gymnastics so as not to misinterpret it. - For ease of mastery of motion in gymnastics, it is necessary to explain in more detail related to the steps and phases of each movement.
Media and technology	- In addition to using links, this product should be able to be used in other versions and models, such as Pdf and video forms that can be accessed offline. - Add a cover with a more varied and interesting background.
Language	- Improve punctuation, writing and use of Indonesian according to the method.

Field trial analysis (effectiveness)

Descriptive analysis of the experimental and conventional groups from each movement phase of the back rolling skill, obtained averages for round back rolling (8.61>7.59), straddle back rolling (8.99>7.55), and corner back rolling (8.88>7.51) (Table 7). Then, the back rolling skills for all phases of movement in the experimental and conventional groups, obtained average (8.82>7.55) (Table 8). In addition, normality and homogeneity tests concluded that the data met the requirements for further analysis (Table 9 and Figure 6).

Table 7. Descriptive analysis of back rolling skills for each movement phase

Group	Data	*N*	Minimum	Maximum	*M ± SD*
Experiment	Round back rolling	33	7.67	10.00	8.61± 0.74
	Straddle back rolling	33	7.67	10.00	8.99± 0.73
	Corner back rolling	33	7.67	9.67	8.88± 0.56
Conventional	Round back rolling	31	5.67	9.67	7.59± 1.05
	Straddle back rolling	31	4.33	9.67	7.55± 0.93
	Corner back rolling	31	4.67	9.67	7.51± 0.86

Table 8. Descriptive analysis of back rolling skills for all movement phases

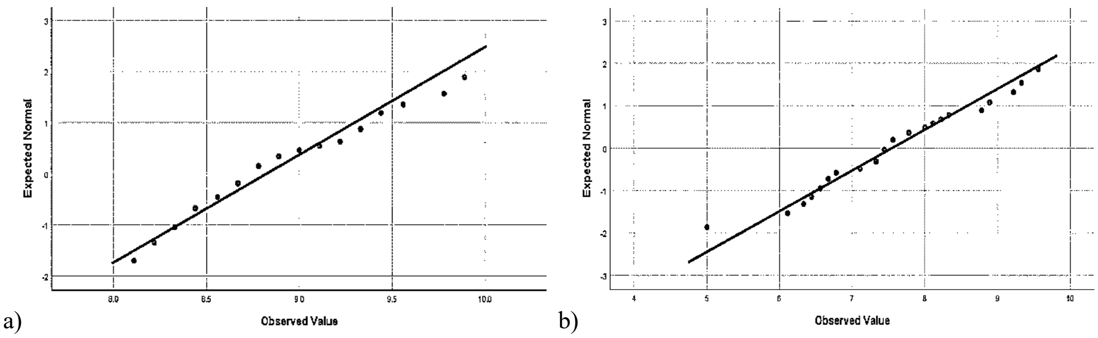
Deskriptive		Experiments (*n*=33)		Conventional (*n*=31)	
		Stattistic	Std. Error	Stattistic	Std. Error
Mean (M)		8.8245	0.08256	7.5481	0.18713
95% Confidence Interval for Mean	Lower Bound	8.6564		7.1659	
	Upper Bound	8.9927		7.9302	
5% Trimmed Mean		8.8075		7.5605	

Median	8.6700		7.4400	
Variance	0.225		1.086	
Std. Deviation (SD)	0.47428		1.04190	
Minimum	8.11		5.00	
Maximum	9.89		9.56	
Range	1.78		4.56	
Interquartile Range	0.84		1.55	
Skewness	0.542	0.409	-0.009	0.421
Kurtosis	-0.486	0.798	0.042	0.821

Table 9. Summary of data analysis requirements

Group	*N*	Normality test				Homogeneity test
		Kolmogorov-smirnov		Shapiro-Wilk		Levene's (*P*)
		Statistic	*P*	Statistic	*P*	
Experiment	33	0.143	0.082	0.949	0.121	0.56
Conventional	31	0.108	0.200	0.975	0.652	

Normal and homogeneous ($P>0.05$).



a) b)

Figure 6. a) Normality plot for experimental group, and b) conventional

The results of the independent sample t-test showed that there was a significant difference between the experimental and conventional groups ($P<0.05$) (Table 10). This is evidenced by the average value of back rolling skills, that the average for the experimental group was 8.82 and the conventional group was 7.55, with a difference was 1.27 (Table 8).

Table 10. Summary of analysis of differences between experimental and conventional groups

Equal variances		t-test for Equality of Means						
		t	*Df*	*P* (2-tailed)	Mean Difference	Std. Error Difference	95% CI	
							Lower	Upper
Gymnastics	Equal variances assumed	6.373	62	0.000	1.2764	0.2003	0.8760	1.6769
	Equal variances not assumed	6.241	41.347	0.000	1.2764	0.2045	0.8635	1.6894

The difference was significant ($P<0.05$).

With regard to the results of this test, so it needs to be analyzed further with the N-Gain score to find out how effective the digital-based gymnastics learning tool that has been developed is. As presented in Table 11, the results of the N-Gain score analysis show that the digital-based gymnastics learning tool developed is moderately effective in improving gymnastics skills in undergraduate sports education students (60.74).

Table 11. N-Gain score analysis

	N	Minimum	Maximum	*M* ± *SD*
Ngain_Score	33	0.51	0.76	0.6074 ± 0.0692
Ngain_percentage	33	50.94	75.56	60.74 ± 6.920
Valid N (listwise)	33			

Discussion

The digital-based gymnastics learning tools that has been developed has met the feasibility indicators, where the *V* and *ICC* index values are in the high category. Field trials also showed that digital-based gymnastics learning tools were proven to be effective in improving back rolling skills ($P<0.05$), with the results of the N-Gain score analysis being in the moderately effective category (60.74). In other words, student engagement in digital technology-assisted teaching has been proven to be effective compared to traditional pedagogy. Previous studies report that digital technology is innovative compared to traditional (conventional) teaching, and its impact is significant on cognitive aspects (Dania et al., 2011). Several other studies report that technology plays a role in producing successful learning activities (Shoraevna et al., 2021), and more fun (Gómez-Carrasco et al., 2020), so that there is student motivation and involvement in achieving learning goals (Oluwajana et al., 2019). In addition, technological assistance in sports performance is also frequently used and proven to be effective for improving better training (Kokarev et al., 2023b; Lisenchuk et al., 2023; Oh et al., 2019).

Content validity in this study involves two or more experts, where they independently provide assessments and evaluate the relevance of the content. Reliability testing also shows that there are no differences in the assessments of each expert, where the *ICC* value is used to analyze this (Koo & Li, 2016). According to Almanasreh et al., the content validity index of developing an instrument is as important as other types of construct validation, so it must be carried out and reported (Almanasreh et al., 2019). Content validity is obtained from experts to provide assessments and evaluate its relevance related to content aspects (Heale & Twycross, 2015; Larsson et al., 2015). The selection and involvement of experts in reviewing and criticizing the content of an instrument must be based on clear criteria (e.g relevant qualifications, experience and expertise) (Almanasreh et al., 2019). Meanwhile, *ICC* is a reliability index that is widely used in test-retest, intrarater and inter-rater reliability analysis (Koo & Li, 2016).

All processes and stages of this product development have been tried as best as possible. However, there are several limitations to these findings. The field trial only focused on one of the materials in this product, namely back rolling skills, so effectiveness tests were needed on other materials. In addition, broader measures of the number of experts and trial samples are needed in future research.

Conclusion

These findings present a product in the form of a digital-based gymnastics learning tool for undergraduate sports education students. This product has gone through feasibility trials from experts as a requirement to meet the intervention quality criteria (content validity), where the results of the V index and ICC for e-learning plans was 0.812 and 0.736. Meanwhile for the e-module was 0.825 and 0.754. In addition, field trials show that this product can improve back rolling skills in gymnastics learning, where the average value of back rolling skills in the experimental group was 8.82 and conventional was 7.55, with a difference was 1.27. The effectiveness of this product is also proven by the results of the N-Gain score analysis, that this product is moderately effective in improving back rolling skills (60.74). The development of digital-based gymnastics learning tools has basically provided an overview of the implementation of gymnastics learning that is relevant to student characteristics and technological developments in higher education. The use of e-learning plans and e-modules in this learning is not only to improve gymnastics movement skills in undergraduate sports education students, but also improves the quality of learning cognitively and affectively. Thus, it is hoped that this digital-based gymnastics learning tool can overcome limitations in learning gymnastics movements, whether used by students, lecturers and practitioners. Future research is needed with larger sample sizes, more refined product displays, and other movements in gymnastics.

Conflict of interest

The authors report no potential conflicts of interest.

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