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Design and implementation of VR *lato-lato* STEAM in engineering education science

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ABSTRACT

This research focuses on integrating science, technology, engineering, art, and mathematics (STEAM) and virtual reality (VR) in engineering-science education through a *lato-lato* game (clackers ball). The research analyzes the development trends of VR, particularly the integration of the *lato-lato* game in STEAM education. Using a waterfall model, the research develops and tests VR-STEAM applications, involving analysis, design, development, and testing phases, with expert validation and student implementation. Data was collected from 60 Indonesian university students and analyzed using partial least squares structural equation modeling (PLS-SEM). Over the past 5 years, VR in education has surged, enhancing learning outcomes and student engagement. The study shows that integrating technology and pedagogy is crucial for effective STEAM education. The design of VR-STEAM is validated and ready for use. PLS-SEM analysis indicates that the indicators are valid and reliable for measuring university students' experiences. The study reveals that integrating STEAM with VR significantly enhances engineering-science learning (ESL), focusing on understanding, personal goals, communication, and cooperation. VR serves as a mediator that fosters 21st-century skills. The research recommends developing assessment tools to measure VR-STEAM ethnoscience and evaluate effectiveness, highlighting the importance of technology in improving learning and connecting concepts to real-world phenomena like *lato-lato*.

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1. INTRODUCTION

The worldwide trend toward digitalization comes increased importance for renewable learning technologies post-pandemic around the world [1], [2]. University education is responsible for guiding students in enhancing knowledge and fostering creativity [3], [4]. The responsibility of managing education has many challenges and obstacles in its development. One of them is the low implementation of technology in science-engineering education [5]–[7]. It impacts the need for more knowledge and competence when becoming a teacher. Additionally, when technology is not effectively integrated into engineering education, students may graduate with outdated skills that do not align with industry standards [8]. This can hinder their employability and effectiveness as engineers.

Therefore, efforts to utilize technology in engineering education are needed. In this case, technology-supported engineering education is more effective than conventional engineering education [8]. Technology support encourages students to learn factual knowledge in engineering education [9], [10]. Technology can also enhance the learning process by providing interactive simulations, virtual labs, and collaborative tools. Virtual technology makes improving students' understanding easier because it can present abstract material [11]. It can be used as a learning medium that can support students in obtaining information and achieving learning objectives. One of the uses of technology in learning that can be used as a learning resource is the use of virtual reality (VR) media in engineering and science education. VR technology is part of learning technologies for promoting 4th sustainable development goals (SDGs) -quality education- especially in universities [12].

VR displays three-dimensional (3D) images in a computer to make it look real with the help of specific tools where users are directly involved in the environmental conditions [13]. In the technology-based learning environment built by VR, users will get immersive and interactive experiences to realize autonomous learning in a real environment [14], [15]. Students can collaborate within virtual environments, working on group projects, and sharing ideas in real time. This interactive element can mimic real-world problem-solving, which is an essential skill in science, technology, engineering, art, and mathematics (STEAM) fields. Empirical evidence showed that utilizing VR in engineering or science education significantly improve students' learning outcomes [16]–[18]. Moreover, learning resources using technology and integrated with the real teaching environment is one of the learning philosophies of STEAM [19]. The use of such technology enables learners to learn knowledge while stimulating creativity and imagination.

The STEAM approach can be used to improve curriculum and teaching quality. STEAM can integrate the five disciplines of STEAM in an interconnected learning approach based on real-world applications [20]. One of the viral games in Indonesia that can be used for STEAM learning media is *lato-lato*, another name for the USA clackers ball, as shown in Figure 1. *Lato-lato* contains various physics elements in the game's rules [21]. Because of its uniqueness and popularity, this game is viral in Indonesia. If associated with learning, the *lato-lato* phenomenon in Indonesia can be used to overcome engineering education difficulties in students. In addition, physics teachers must innovate to maintain meaningful learning through real experiences such as those found in the *lato-lato* phenomenon.

There are limited known studies on the use of *lato-lato* in VR within STEAM education, especially in engineering. Some of the early research are focused on general VR applications rather than cultural integration. The complexity of combining cultural elements like *lato-lato* with VR technology requires interdisciplinary knowledge. Additionally, the lack of studies might not mean that such tools are absent in the market, but they must be thoroughly evaluated in academic literature. This study is crucial because it enhances engineering education by making learning more culturally relevant, engaging, fills a gap in existing research, and promotes further exploration of integrating ethnoscience into STEAM education.

Therefore, this research was conducted to integrate STEAM into VR technology based on *lato-lato* game. Specifically, this research aims to: i) analyzing research trends related to VR *lato-lato* STEAM in engineering education; ii) design VR *lato-lato* Steam and analyze validity and reliability; and iii) analyzing the hypothetical model of VR *lato-lato* STEAM related to student response. By incorporating cutting-edge technology like VR with *lato-lato*, students are better prepared for future careers in fields that rely on STEAM skills. They gain experience with tools and methods relevant to modern industries. To achieve this objective, authors designed an VR application and questionnaire.

Figure 1. The *lato-lato*

2. METHOD

2.1. Research design

This research type is research and development (RnD) with a waterfall model to develop and test products. This research model consists of all project phases (analysis, design, development, and testing) with each phase finishing up entirely before the start of the following [22]. The authors use bibliometric analysis as preliminary research to analyze the importance of developing VR-STEAM in engineering science education [23]. In the design and development stage, authors constructed VR using Blender modeled to create *lato-lato*, and visual studio and C# programming are used for script logic. Expert validated the VR product. In the testing stage, students can implement VR-STEAM applications in their learning activities. After learning, the authors distributed surveys. The survey data were analyzed by using partial least squares structural equation modeling (PLS-SEM) to explore model fit and correlation among exogen and endogen variables [24].

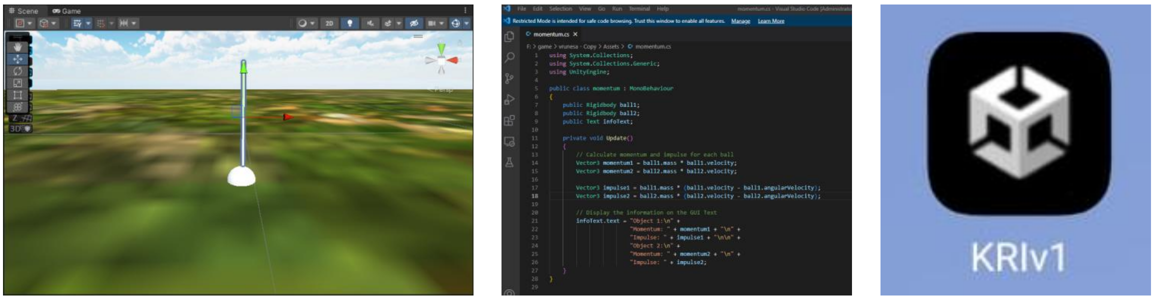
2.2. Sample and data collection

Scopus database support bibliometric analysis to research trend on VR and STEAM in education [25]. Data were gathered from Scopus, because it is one of the most important sources of scientific literature. The validation sheets are distributed to three experts. Therefore, 60 engineering-science university students in Indonesia participated in survey.

2.3. The instrument and VR product

The instruments used in making VR are using Unity software in making products, Meta Quest Developer Hub software to upload software to Oculus to install, Blender to create objects used in applications and Oculus hardware to play applications that have been made. The authors constructed VR products and validated them before students learned with VR-STEAM. Figure 2 shows the process of developing VR-STEAM specifically Figure 2(a) shows about VR Modeling, Figure 2(b) shows about script function and logic in program creation, and Figure 2(c) shows about the compile result of VR-STEAM application on Android.

The instruments used in this research are validation sheets and questionnaires. The validation product sheets include software accuracy, user comfort, and easy interaction. The questionnaire consists of four variables and uses four-point Likert scale. Every variable consists of three indicators. Table 1 represents a detailed questionnaire instrument used in this research.



(a) (b) (c)

Figure 2. Process of developing (a) VR modelling, (b) functions and logic, and (c) VR-STEAM application on Android

2.4. Data analysis

2.4.1. Bibliometric analysis

A network visualization was created and seen by VOSviewer using .ris metadata. Next, the data was plotted and categorized using Microsoft Excel and .csv metadata. Software utilized for data analysis in bibliometric study includes Microsoft Excel and VOSviewer. Network visualizations were created and viewed by VOSviewer using extension. ris metadata. Furthermore, the data was plotted and categorized using Microsoft Excel and .csv metadata. Software used for data analysis in bibliometric studies include Microsoft Excel and VOSviewer. The bibliometric analysis step in the waterfall model lies in system design (bibliometric systems can help in designing the system), implementation (bibliometrics is used to measure the performance of the system by referring to the metrics proposed in the literature), testing (the results of the developed application can be compared with findings from bibliometric studies) and maintenance (helps in identifying areas for improvement based on user feedback and new literature) [26].

Table 1. Questionnaire instrument

Category	Description	Indicator	Code
STEAM	Students' thoughts on STEAM content	The *lato-lato* game is suitable as an interesting content or stimulus for engineering-science learning (ESL).	STEAM1
		The *lato-lato* used in STEAM can make learning more enjoyable.	STEAM2
		The *lato-lato* game can motivate students to learning engineering and science.	STEAM3
Engineering science learning (ESL)	Students' thoughts of VR-STEAM learning	There is clear correlation between STEAM and VR during learning activities	ESL1
		VR-STEAM is interesting in engineering-science learning	ESL2
		VR-STEAM can improve understanding physics concept	ESL3
Virtual reality product (VRP)	Students' opinion on VR-STEAM as learning media	VR-STEAM product is easy to use	VRP1
		VR-STEAM product can deliver STEAM content clearly	VRP2
		VR-STEAM is the best solution for engineering-science learning	VRP3
Students' responses (SR)	Students' feels after implement VR-STEAM	Improve cooperation among students	SR1
		Students have good knowledge about *lato-lato* and STEAM	SR2
		Students try their best to solve engineering-science problems (motivation)	SR3

2.4.2. Validation of VR product

The validity of VR-STEAM is assessed quantitatively using the results from the validity sheets. Data from validity were descriptively examined with modus. According to the validity requirements stated in Table 2, the modus was got. If VR-STEAM receives more than three modes of data, it is considered valid. Specifically in Table 2, the validity criteria used modus value 1 is invalid, modus value 2 is enough, modus value 3 is valid, and modus value 4 is very valid.

Table 2. The validity criteria

Modus value	Description
1	Invalid
2	Enough
3	Valid
4	Very valid

2.4.3. PLS-SEM analysis

PLS-SEM includes both factor analysis and multiple regression analysis. In this study, PLS-SEM was performed using SmartPLS 4. The findings consist of two key elements: the structural model, which investigates the relationships among latent variables, and the measurement model, which evaluates the relationships between latent variables and their indicators. This analysis focused on determining the structural connections among the variables. There are various criteria that need to be fulfilled for conducting a PLS-SEM analysis:

- Convergent validity: this is evaluated by looking at the loading factor value which is used to show the relationship between latent variables and their indicators. A latent variable and its indicator are considered valid if the loading factor is greater than 0.7 [27].
- Reliability: this is determined by the values of Cronbach alpha and composite reliability. For reliability to be established, the minimum value of Cronbach alpha is required to be 0.6 or the value of composite reliability is 0.7 [28].
- Average variance extracted (AVE): AVE value of at least 0.5 to be classified as good and serves as an indicator of convergent validity [27].
- Effect size (F square): a minimum value of 0.35 is needed to indicate a well-fitting model [29], [30].
- Discriminant validity: This is assessed through cross-loading values above 0.7, the heterotrait-monotrait (HTMT) ratio, and the Fornell-Larcker criterion which should be below 0.9 [31].
- Model fit: the standardized root mean square residual (SRMR) should range from 0.05 to 0.08, while the normed fit index (NFI) should fall between 0.8 and 0.9 [32], [33].
- Hypothesis testing: for a hypothesis to be valid, the p-value must be less than 0.05, while the t-statistic must exceed 1.96 so that it can be used to indicate a significant relationship between the variables [25], [27].

3. RESULTS AND DISCUSSION

3.1. Research trends related to VR *lato-lato* STEAM in engineering education based on bibliometric analysis

Figure 3 illustrate the significant increase in the trend of VR research in education in the last 5 year. This is because emerging technologies in education have become more common in recent years, and VR has become an important tool for learning and teaching by changing the way learning materials are delivered in education [34]. Empirical evidence has shown that using VR in education can improve learning outcomes and increase student engagement and motivation [35], [36]. Additionally, previous research conducted a bibliometric analysis on VR that has the transformative potential of VR technology in improving educational practices [37], potential to transform traditional language learning approaches, and thorough bibliometric analysis of VR providing a roadmap for future research directions [38].

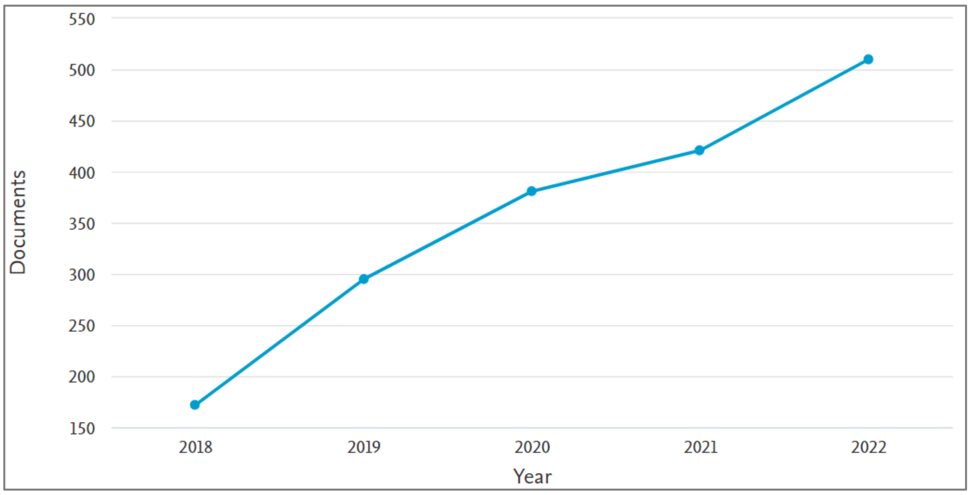


Figure 3. Research trend of VR in education by year

Figure 4 shows a network visualization of the research trend of VR in education and learning. It can be inferred that VR in education point to a dynamic and interdisciplinary landscape where the integration of technology and pedagogy takes center stage. Notably, the prevalence of keywords such as 'VR' and 'E-learning' reflects a thriving intersection of technology and education, with researchers collaborating across disciplines to enhance educational outcomes. The prominent presence of terms like 'students' and 'learning' underscores a strong focus on student-centric learning, with VR potential to revolutionize engagement and personalization in education.

Furthermore, the 'human' keyword suggests a holistic approach to understanding the cognitive and emotional impact of VR on learners. 'Learning systems' highlights the importance of the technological infrastructure, while 'augmented reality' hints at the exploration of a broader spectrum of immersive technologies in education. Additionally, 'engineering education' signifies the emergence of specialized applications of VR in specific fields within education. Finally, 'computer aided instruction' underscores the development of pedagogical tools that leverage VR technology, emphasizing the need to effectively integrate it into curricula. Collectively, these findings reflect an exciting synergy between technology, pedagogy, and the human element, which is shaping the future of VR in education, promising more engaging and effective learning experiences for students across various disciplines [39], [40].

Meanwhile, Figure 5 shows the details of the node link between STEAM and VR. In terms of STEAM education (Figure 5), there are links between steam and VR alongside e-learning. The presence of these links implies that STEAM educators are actively seeking innovative ways to teach and engage students. VR and e-learning offer opportunities for personalized, interactive, and experiential learning experiences in STEAM subjects. This connection underscores the importance of exploring modern pedagogical approaches to keep STEAM education relevant and effective. Moreover, VR allows for the creation of interactive simulations and experiments. In STEAM subjects, this can be invaluable for conducting experiments that might be too expensive, dangerous, or impractical to perform in a traditional classroom. Students can engage with physics experiments, including *lato-lato*, in a safe and controlled virtual environment.

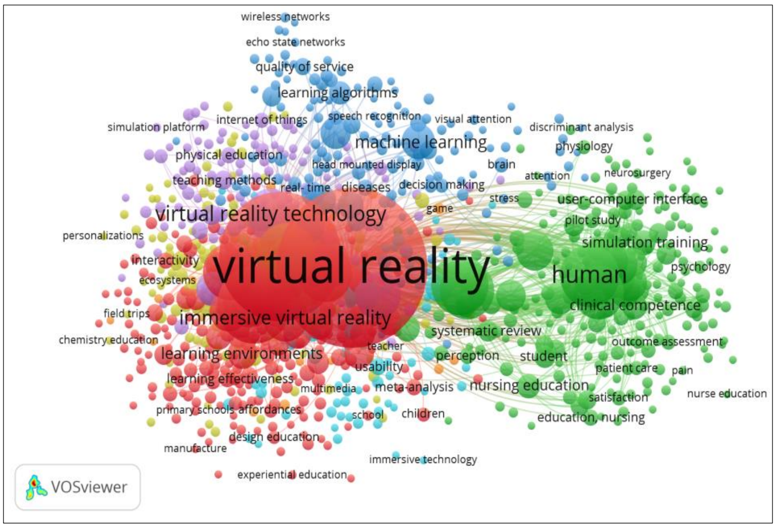


Figure 4. Visual network of VR research keywords

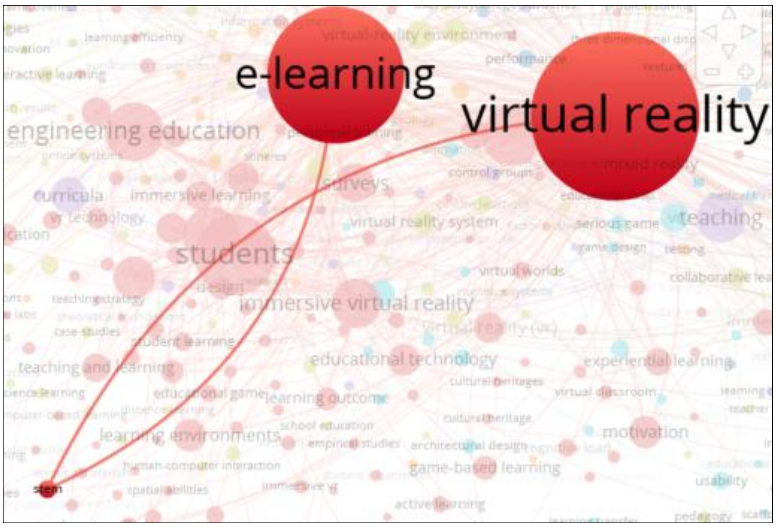


Figure 5. Node link between STEAM and VR

3.2. Analysis of validity and reliability of VR *lato-lato* STEAM

The expert argues that VR-STEAM *lato-lato* is valuable for learning momentum and collision concepts in engineering-science education. It incorporates STEAM in ball motion and game display, making abstract concepts more realistic. While some improvements are needed in software appearance, the game's aesthetic appeal is satisfactory. While it may be younger in terms of art and playing, it offers a more practical and more accessible learning experience for mathematics concepts. According to Table 3, VR-STEAM is valid and ready to use.

Table 3. The validation result by expert

Category	Result			Modus	Description
	E1	E2	E3		
Software accuracy	3	4	4	4	Very valid
Program integration	4	3	4	4	Very valid
Display future	3	4	3	3	Valid
Software interaction	2	2	2	2	Enough
UI/UX	3	4	3	3	Valid
User preference	3	4	3	3	Valid
Modus	3	4	3	3	Valid

3.3. Analyze the hypothetical model of VR *lato-lato* STEAM through PLS SEM

The PLS-SEM analysis of the measurement model and structural model and the relationship between variables in the research model shows that the measured variables are consistent with the data, namely evaluation of measurement model and evaluation of structural model.

3.3.1. Evaluation of measurement model

The validity includes convergent and discriminant validity. Convergent validity consists of loading factor and AVE. According to Figure 6 and Table 4, all construct gets loading factor >0.7; CA>0.6; CR>0.7. Loading factor higher than 0.70 are indicated since they satisfactorily account for roughly 50% of the variance of the indicators and give satisfactory item dependability [36]. Thus, the latent variables have been satisfactorily and consistently explained by the four provided variables. CR levels are considered adequate to good when they range between 0.70 and 0.90 [41].

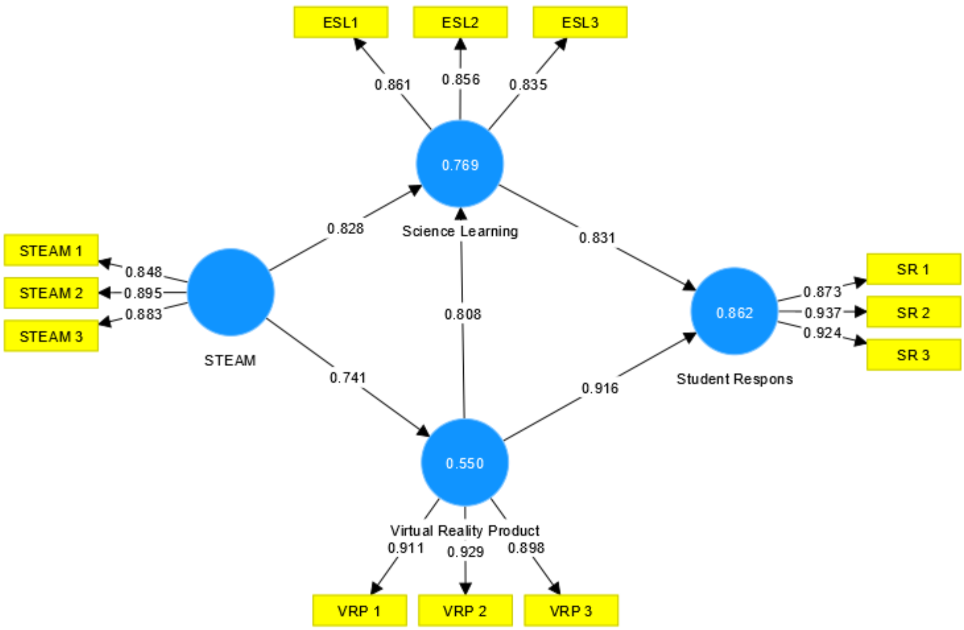


Figure 6. Hypothetic model

Table 4. Convergent validity and reliability

Variable	Cronbach's alpha	p_a	p_b	AVE
STEAM	0.848	0.860	0.908	0.766
ESL	0.811	0.817	0.887	0.724
SR	0.898	0.900	0.937	0.832
VRP	0.900	0.900	0.937	0.833

Additionally, the discriminant validity of the measurement model was examined to determine whether the latent variables being investigated in this study could be discriminated. A specific latent variable's discriminant validity indicates how different it is from other latent variables. In addition, discriminant validity consists of HTMT, VIF model, and cross loading. Fornell-Larcker results in Table 5 represent acceptable discriminant validity because the inter-correlation between constructs is smaller than the square roots of AVE and HTMT [34]. Results in Table 6 represent a basic statistical discriminant validity test.

Table 5. Fornell-Larcker results

Variable	STEAM	ESL	SR	VRP
STEAM	0.875			
ESL	0.828	0.851		
SR	0.731	0.831	0.912	
VRP	0.741	0.808	0.916	0.913

Table 6. HTMT

Variable	STEAM	ESL	SR	VRP
STEAM				
ESL	0.9			
SR	0.8	0.9		
VRP	0.8	0.9	1.0	

The HTMT ratios are below 0.9 for all constructs, except for VRP-SR, which also shows issues in the Fornell-Larcker criterion results. It indicates a problem with the discriminant validity of this construct. Cross-loadings help assess the validity of each variable in relation to its respective indicators. The highlighted values in Table 7 affirm that the outer loadings of each indicator are higher than their cross-loadings within the same construct. Based on the PLS-SEM analysis, each indicator was found to be valid and reliable in measuring university students' responses (SR) and experiences, especially within the context of STEAM education using VR applications. These findings confirm the reliability, convergent validity, and discriminant validity of the indicators.

Table 7. Cross loadings

	STEAM	ESL	SR	VRP
ESL1	0.691	0.861	0.634	0.541
ESL2	0.762	0.856	0.645	0.606
ESL3	0.663	0.835	0.814	0.872
SR1	0.689	0.773	0.873	0.793
SR2	0.650	0.782	0.937	0.857
SR3	0.662	0.719	0.924	0.854
STEAM1	0.848	0.651	0.546	0.554
STEAM2	0.895	0.681	0.633	0.667
STEAM3	0.883	0.823	0.722	0.710
VRP1	0.653	0.736	0.827	0.911
VRP2	0.699	0.750	0.800	0.929
CRP3	0.678	0.726	0.879	0.898

3.3.2. Evaluation of structural model

According to Table 8, NFI get 68.1% so the hypothetic model was enough fit. R-square represents how far variable influence in structural model. SR get the highest percentage 86.2% and VRP get 55.2%. There are 30-50% another variable is participated. F-square represents how fit variable in structural model. F-square in Figure 7 is higher than 0.35 so each variable is fit and accepted.

Table 8. R-square and model fit

Variable	R-square	Indicator model fit	Value
ESL	0.769	SRMR	0.094
SR	0.862	Chi-square	0.852
VRP	0.552	NFI	0.681

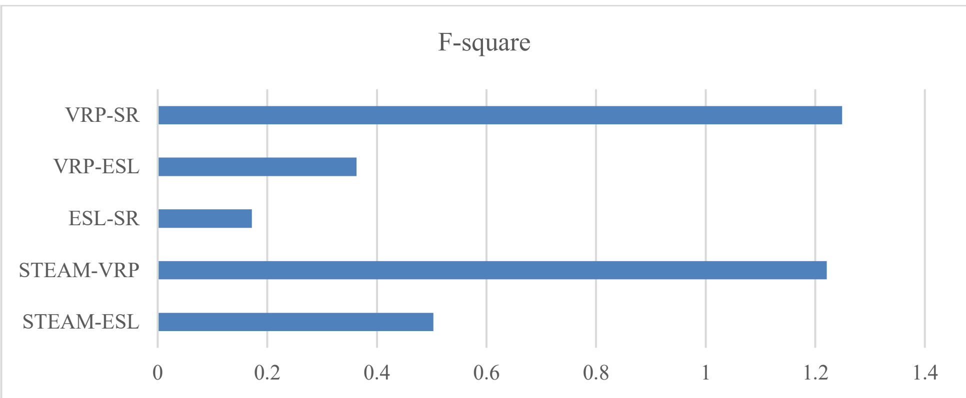


Figure 7. F-square

A total of five significant paths were discovered, as shown in Table 9. Path coefficient represents how much a variable influence other variable. Path STEAM-ESL get highest coef. in total effects, STEAM-SR get 0.739 in indirect effects; then, STEAM-VRP and VRP-SR get highest direct effects. The influencing factors of STEAM are directly from the two constructs ESL and VRP. It represents STEAM integrated with VR has a direct significant positive impact to engineering-science learning. Then, implement VR-STEAM in learning can give direct significant positive impact to SR.

Table 10 indicates the explanation of the path in hypothesis model regarding positive coefficients, t-stat, and p-value. All path gets positive coef., t-stat, and p-value <0.05. It represents implement VR integrate STEAM in engineering-science learning positive impacted to students' response (cooperation, motivation, and knowledge) significantly. In other words, SR due to VR-STEAM crucial for their future engineering-science learning.

VR as technology education, cooperation, motivation, and knowledge about ethnoscience (local wisdom combined science) can be promoted by exploring the essence of science and technology education. It focuses on understanding, personal goals, communication character, and cooperation. It can be found that VR-STEAM *lato-lato* contributes to 21st-century skills, as shown in Figure 8. The skills essential for the 21st century, particularly cooperation, play a key role in the foundational perspective of STEAM education and engineering-science learning [41]. This study's model demonstrated that VR serves as a mediator between STEAM content and engineering-science learning. In essence, the impact of VR on students' skills is derived from STEAM material. Researchers should persist in their efforts to create assessment tools that evaluate how to measure the integration of VR with STEAM and ethnoscience, and to determine whether this ethnoscience-integrated STEAM can be taught as a standalone subject to facilitate 21st-century learning, or if it instead indirectly fosters the necessary skills through STEAM.

Table 9. Total, indirect, and direct effects

Path	Total effects				Indirect effects				Direct effects coef.
	Value	Coef.	T-stat	P-value	Value	Coef.	T-stat	P-value	
STEAM -ESL	0.828	0.828	19.163	0.000	0.320	0.320	3.165	0.002	0.508
STEAM-SR	0.739	0.739	11.251	0.000	0.739	0.739	11.251	0.000	
STEAM-VRP	0.741	0.741	10.288	0.000					0.741
ESL-SR	0.261	0.261	1.911	0.057					0.261
VRP-SL	0.432	0.432	3.480	0.001					0.432
VRP-SR	0.817	0.817	11.084	0.000	0.113	0.113	1.361	0.174	0.704

Table 10. Path in hypothetic model

Path	Coef.	T-stat	P-value
STEAM-ESL	0.508	4.754	0.00
STEAM-VRP	0.741	10.288	0.00
ESL-SR	0.261	1.911	0.05
VRP-ESL	0.432	3.480	0.00
VRP-SR	0.704	5.031	0.00

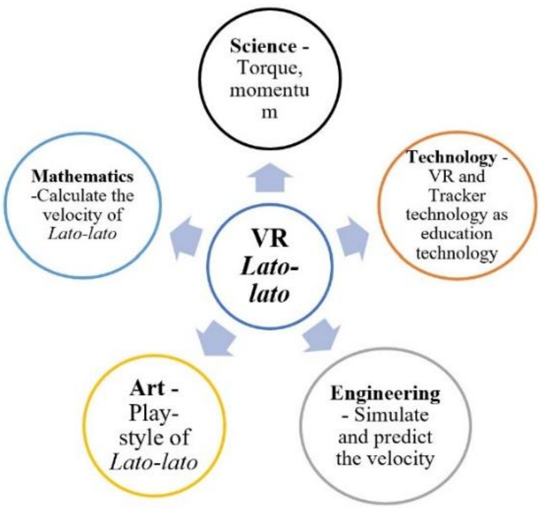


Figure 8. STEAM in VR-*lato lato*

This study developed and validated indicates to help evaluate VR-STEAM learning tools integrated ethnoscience *lato-lato*, helping instructors and university students choose the best fit for their students. All efforts to integrate technology into enhanced learning, especially in engineering education, aim to increase student motivation, curiosity, and problem-solving skills, as demonstrated by the integration of VR *lato-lato* in STEAM education [42]–[46]. In addition, game learning on VR *lato-lato* in STEAM education can change inter of student's competencies and behaviors while in class [47], [48].

4. CONCLUSION

Based on the results and discussion, several key conclusions can be drawn about using VR *lato-lato* in STEAM education, especially in engineering. First, there has been a significant rise in VR research in education over the past five years, highlighting its potential to enhance student engagement and learning outcomes. This trend reflects a collaborative effort among educators to integrate technology into teaching, making learning more interactive and practical. Second, the VR *lato-lato* tool has been validated as a valuable resource for teaching complex concepts like momentum and collisions, offering an engaging way for students to understand these ideas. Lastly, the analysis shows that integrating VR into STEAM education positively influences students' motivation and understanding, ultimately equipping them with essential skills for the 21st century. These findings emphasize the importance of continuing to explore and develop VR applications in education to enhance learning experiences.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

The datasets generated during and/or analyzed during the current study are available in this link: http://dx.doi.org/10.6084/m9.figshare.28673930. This data set was proposed in .csv. and process in VOSviewer, Microsoft Excel, and SMART PLS.

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