



Modelling teacher pedagogical readiness for STEAM: a factor analysis

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Abstract. *Introduction.* In the context of global technological transformation, which is shaping new directions for the development of educational systems, research focused on preparing teaching staff for the implementation of integrative approaches is particularly relevant. *Aim.* This research aims to develop and evaluate a structural model that assesses the readiness of future physics teachers to implement the STEM approach in their professional practice. *Methodology and research methods.* The methodological foundation was a quantitative descriptive approach, employing procedures of Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA). The empirical basis of the study comprised the results of a survey of 408 students from three universities in East Java, Indonesia. *Results.* It was established that the overall level of readiness of future physics teachers to implement the STEM approach is 81.67%. Based on factor analysis, the key components of the integrative model were identified and conceptualised as Engineering, Arts, Religion, and Social components. *Scientific novelty.* The scientific novelty of this research lies in the theoretical justification and empirical identification of the core element of future educators' professional training, termed "Basic Understanding", which ensures the integrity and inter-connection of these components. This facilitated the synthesis and structural representation of the evolution of integrative educational models from STEM to STEAM, STREAM, and, ultimately, to the STEAMS model proposed by the authors. *Practical significance.* The practical significance of this study lies in its potential to modernise the content of curricula, programmes, and pedagogical methods within the professional training system for physics teachers and other science disciplines, with the aim of enhancing their comprehensive readiness to implement interdisciplinary educational strategies.

Keywords: teacher education, physics teacher training, STEM education, STEAM, STREAM, integrative model, factor analysis, professional readiness

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Моделирование педагогической готовности учителя к STEAM: факторный анализ

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Аннотация. Введение. В контексте глобальной технологической трансформации, определяющей новые векторы развития образовательных систем, особую актуальность приобретает исследование, посвященные подготовке педагогических кадров к реализации интегративных подходов. Цель. Данная работа посвящена разработке и апробации структурной модели готовности будущих учителей физики к применению STEM-подхода в профессиональной деятельности. Методология, методы и методики. Методологическую основу составил количественный описательный метод с применением процедур эксплораторного (EFA) и конфирматорного (CFA) факторного анализа. Эмпирическую базу исследования сформировали результаты анкетирования 408 студентов трех университетов Восточной Явы (Индонезия). Результаты. Установлено, что общий уровень готовности будущих учителей физики к реализации STEM-подхода составляет 81,67 %. На основе факторного анализа были идентифицированы и концептуализированы ключевые составляющие интегративной модели: инженерная (Engineering), художественная (Arts), религиозная (Religion) и социальная (Social) компоненты. Научная новизна исследования заключается в теоретическом обосновании и эмпирическом выделении системообразующего элемента профессиональной подготовки будущих педагогов «Базовое понимание» (Basic Understanding), который обеспечивает целостность и взаимосвязь указанных компонентов. Это позволило синтезировать и структурно представить эволюцию интегративных образовательных моделей от STEM к STEAM, STREAM и, в конечном итоге, к предложенной авторами модели STEAMS. Практическая значимость работы определяется возможностью применения ее результатов для модернизации содержания учебных планов, программ и педагогических методик в системе профессиональной подготовки учителей физики и других естественнонаучных дисциплин с целью формирования их комплексной готовности к реализации междисциплинарных образовательных стратегий.

Ключевые слова: педагогическое образование, подготовка учителей физики, STEM-образование, STEAM, STREAM, интегративная модель, факторный анализ, профессиональная готовность

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Introduction

The transformation of education from the 4.0 to 5.0 era requires a more integrated and contextual approach to the learning process. This aims to improve the quality of education through the SDGs 4 programme [1, 2]. According to N. C. Burbules, G. Fan, P. Repp [3] and S. Adipat, K. Laksana, K. Busayanon et al. [4], quality education can be achieved through scientific and technology-based approaches to the learning process. Through this statement, it is hoped that using a scientific and technology-based approaches will result in quality education for human resource development.

Through science- and technology-based, it is hoped that students will be able to think scientifically and logically. This view is supported by Muthmainnah, P. M. I. Seraj, I. Oteir [5] and I. A. Rizki, N. Suprpto [6], who identified the important role of science and technology in developing students' scientific and logical thinking. Students, who have the scientific and logical abilities to solve contextual problems, think critically and creatively [7, 8]. Consequently, teachers must be competent in delivering this approach [9, 10]. Achieving this competency necessitates practical fieldwork in implementing science and technology-based learning.

In fact, there are still few implementations of learning using scientific and technology-based approaches. This view is corroborated by studies which show that the use of science and technology-based learning practices in Indonesia is still minimal [11–13]. This fact shows that teachers still have a minimal understanding of scientific and technology-based approaches in teaching practice. According to S. Baroudi and M. R. Helder [14], if teachers have minimal experience in using science and technology, then the standardisation of quality education that prioritises science and technology will lag behind. Therefore, there needs to be a dedication to teachers, especially prospective teachers, to provide an understanding of scientific and technology-based approaches in learning [15, 16].

Prospective teachers must understand scientific and technology-based approaches to future learning. The scientific approach plays an important role in learning that aims to shape scientific attitudes and reinforce facts [17]. The technology-based approach is used to complement science learning so that students can understand scientific visualisation [18, 19]. Therefore, there needs to be a strategy for scientific and technology-based approaches through prospective teachers so that the future target of education is quality education.

The scientific and technology-based approaches referred to is the STEM (science, technology, engineering, mathematics) approach. This approach has been proven effective in improving students' conceptual understanding in the context of improving the quality of education [20–23]. In this changing era, the approach is not only limited to science and technology, but also includes elements of art,

religion, and social studies. This development requires the addition of approaches in learning, namely STEM, STEAM, STREAM, and STEAMS with the addition of the elements A (Arts), R (Religion), and S (Social) [24, 25].

The development of this approach requires a deep understanding of both the desert and prospective teachers. It is necessary to observe prospective teachers' understanding of the STEM, STEAM, STREAM, and STEAMS approaches as a learning strategy [26–28]. According to H. O. Khadri [29] and T. P. L. Nguyen, T. H. Nguyen, T. K. Tran [30], providing prospective teachers with an understanding of the STEM approach is necessary because prospective teachers must teach in accordance with current approaches and developments. To begin understanding this approach, it is necessary to have the perspective of prospective teachers in responding to the understanding of STEM, STEAM, STREAM, and STEAMS. Therefore, the research questions in this study can be described as follows:

RQ1: How prepared are prospective physics teachers to support the implementation of STEM, STEAM, STREAM, and STEAMS learning?

RQ2: How does the structural model of readiness of prospective physics teachers support the implementation of STEM, STEAM, STREAM, and STEAMS learning?

This study offers a perspective on STEM development by adding elements of arts, religion, and social studies. The addition of arts, religion, and social studies to STEM has an impact on education in the modern era [24, 31]. This study is limited to respondents who are prospective teachers regarding their readiness and basic understanding of STEM, STEAM, STREAM, and STEAMS in East Java province. This study aims to describe the preparation and identify factors in the implementation of STEM, STEAM, STREAM, and STEAMS.

Literature Review

Pedagogical readiness of prospective teachers

Teachers play an important role in improving the quality of education. Therefore, teachers need to be prepared to face educational challenges in the era of modernisation. According to C. DeLuca, M. Searle, K. Carbone et al. [32], teachers' readiness to face challenges is measured through their basic understanding of knowledge and curriculum. This readiness becomes the foundation for teachers to carry out learning that is in line with current needs. In this aspect, a basic understanding of the components of the approach to be used is the foundation for teachers in facing learning [33, 34]. Therefore, a survey is needed to determine the basic understanding of prospective teachers regarding several learning approaches to be implemented.

Science, technology, mathematics

The learning approaches required are those based in science, technology, and mathematics. According to R. Kumar and K. A. Acharya [17], these three approaches play an important role in learning because they are interconnected. For further clarification, Figure 1 illustrates the interconnection between these three modern learning approaches in line with current needs.

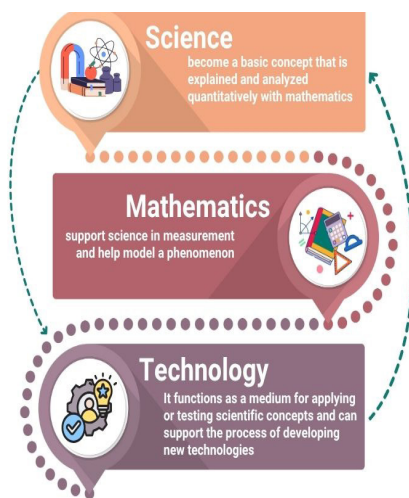


Fig. 1. Relationship between scientific, technology-based and mathematical approaches

Based on Figure 1, science, mathematics, and technology have a reciprocal relationship. The scientific approach has characteristics related to natural phenomena around us in a scientific manner. The mathematical approach has characteristics that assist in measuring natural phenomena that support the scientific approach. The technology-based approach is a combination of science and mathematics, which is the result of its products. The definition and scheme of Figure 1 are reinforced by the statement of S. Belbase, M. A. Al Mutawah, L. Thomas et al. [31] so that this can be a basis for the development of this approach.

The development of STEM-STEAM-STREAM-STEAMS

Scientific, technology-based, mathematical approaches continue to evolve in line with curriculum requirements. In the 4.0 era, scientific, technology-based, mathematical approaches have the addition of engineering (E) and art (A) elements. In the 5.0 era, it has the addition of religion/reading (R) and social (S) elements. The relationship between these approaches can be represented as shown in Figure 2.

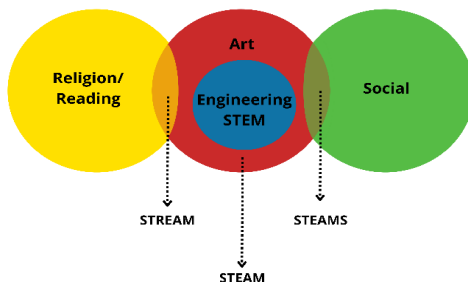


Fig. 2. Relationships in each approach

Based on Figure 2, it shows that each approach has a main element, namely engineering (STEM). Over time, the element of art was added in accordance with the needs of 4.0, thus becoming STEAM [35]. The addition of the element of art aims to add creativity skills, which are essential in the 21st century. The addition of the reading/religion element is tailored to the needs of the society era, which adds value to literacy and religion [24]. The addition of the reading/religion element can be referred to as STREAM, which focuses on literacy and religious values. The addition of the social element is tailored to the society era, which focuses on humanistic or social activities, so this approach is referred to as STEAMS.

Research hypothesis

This study has a hypothesis based on a literature review that is used as reinforcement. Based on research conducted by C. DeLuca, M. Searle, K. Carbone et al. [32], prospective teachers' readiness lies in their basic understanding of the approach to be used. In this context, the approaches used in the study are E, A, R, and S, which means that prospective teachers need to have a basic understanding of the elements of the E, A, R, and S approaches. The structural hypothesis of this study can be illustrated as shown in Figure 3

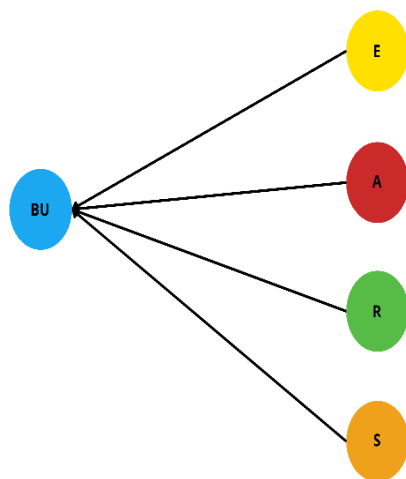


Fig. 3. Framework hypothesis

Methods

Research design

This study uses an exploratory design to evaluate the implications of STEM learning and its development. This study investigates the readiness of prospective physics teachers in implementing STEM learning and its development. Figure 4 shows the exploratory research design, who adapted the research conducted by N. Suprpto [36].

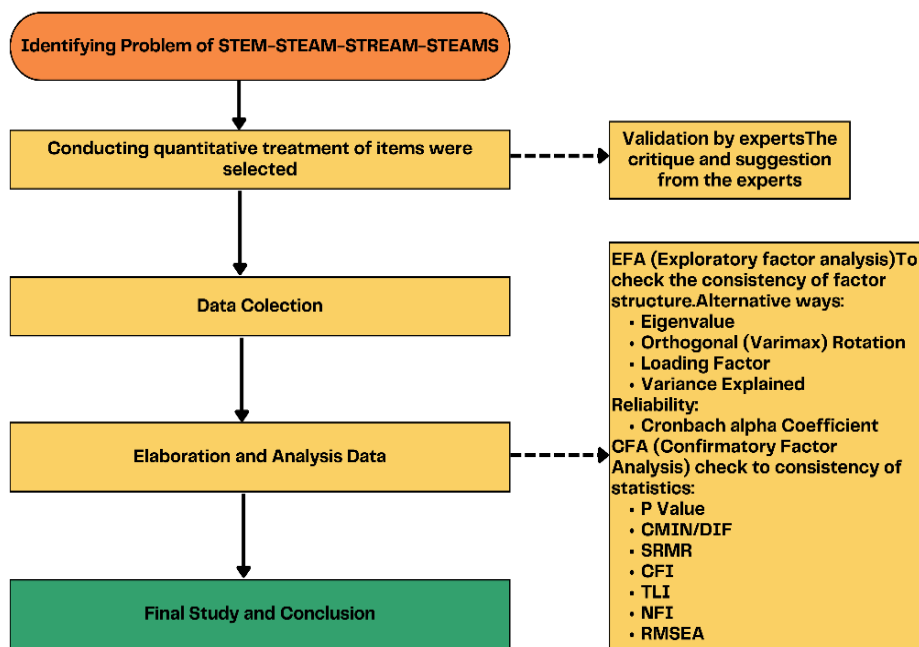


Fig. 4. Research flow chart

This study was conducted in five stages. In the first stage, we identified issues related to STEM, STEAM, STREAM, and STEAMS. In the second stage, we developed a questionnaire for prospective student teachers. In the third stage, we distributed the questionnaire to these prospective student teachers. In the fourth stage, we analysed the responses collected from the questionnaire. In the final stage, we drew conclusions based on the results obtained.

Data collection and data acquisition procedures

The data collection technique was carried out in collaboration with three universities in East Java. To clarify the data collection, we provided a flowchart (Figure 5) of the data collection process adapted from the research by A. S. Adam, H. Mubarok, and N. Suprpto [37].

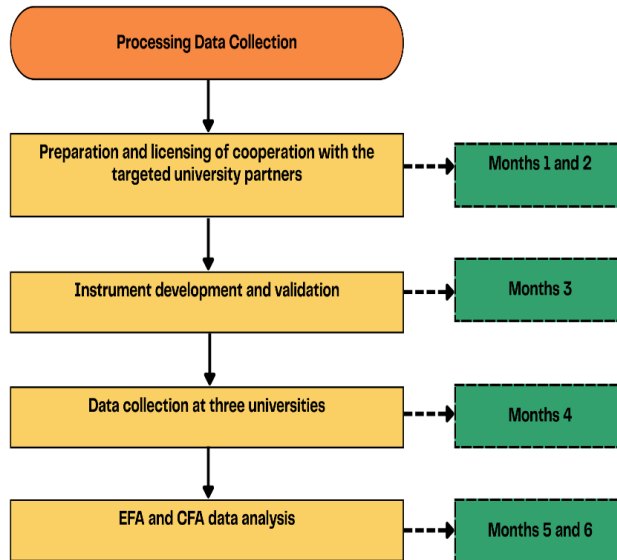


Fig. 5. Research data collection process

The clustered data results were obtained from three universities, namely Malang State University, Jember University, and Surabaya State University. To clarify the data collection clustering results, Table 1 explains the number of clusters obtained.

Table 1

Data clustering

University	
Malang State University	132
Jember University	161
Surabaya State University	115
Semester	
Semester 3	103
Semester 5	137
Semester 7	168

Questionnaire instrument

This study used a questionnaire instrument with Google Forms. The questionnaire questions covered five variables, namely BU (Basic Understanding), STEM, STEAM, STREAM, and STEAMS. Table 2 clarifies the description of the variables used.

Table 2

Description of research variables

Variable	Description
Basic Understanding	This variable includes prospective teachers' understanding of STEM, STEAM, STREAM, and STEAMS in pedagogical terms.
STEM	This variable includes understanding of STEM (Science, Technology, Engineering, Mathematics) elements.
STEAM	This variable includes understanding of STEAM elements (Science, Technology, Engineering, Art, Mathematics).
STREAM	This variable includes an understanding of the STREAM elements (Science, Technology, Religion, Engineering, Arts, Mathematics).
STEAMS	This variable includes understanding of STEAMS elements (Science, Technology, Engineering, Art, Mathematics, Social).

Each variable has four statements that students answer using a 1–4 Likert scale. The Likert scale used ranges from strongly disagree to strongly agree. These statements are intended to elicit responses from various perspectives.

Data analysis

Data analysis in this study was conducted using Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA). This was done because the measurement instruments used were new, requiring EFA as an initial test to explore the factor structure. EFA was used to describe the readiness of prospective teachers, while CFA was used to describe the structural model of pedagogy. In addition, CFA was used to test the predetermined model based on the initial hypothesis [38].

Before running EFA, data suitability was tested using Kaiser–Meyer–Olkin (KMO) and Bartlett's Test of Sphericity [36, 39]. A KMO value ≥ 0.50 indicates that the data is suitable for factor analysis [40]. A statistically significant Bartlett test result indicates that the data is suitable for factor analysis [38, 40]. Furthermore, Cronbach's alpha (α) coefficient was calculated to measure the reliability of each factor produced, and CFA was conducted to validate the construct through cross-validation, with a minimum factor loading of 0.50 [40]. Table 3 explains the CFA statistics that adapt the research of N. Suprpto and A. Mursyid [38], and A. Khademi, C. S. Wells, M. E. Oliveri et al. [41].

Table 3

Statistical values as for confirmatory factor analysis

Measures	Acceptable fit index	Good fit index
P values	-	<0.05
CMIN/DIF	2.0-3.0	<2
NFI	0.90<GFI<0.95	>0.95
TLI	0.90<TLI<0.95	>0.95
CFI	0.90<CFI<0.95	>0.95
SRMR	0.05<SRMR<0.10	<0.05
RMSEA	0.05<RMSEA<0.10	<0.05

Note. RMSEA: Root Mean Square Error of Approximation; GFI: Goodness of Fit Index; TLI: Tucker-Lewis Index; S-RMR: Standardised RMR; CFI: Comparative Fit Index

Results

Readiness of prospective student teachers

Data processing is still in the EFA analysis stage to identify each factor produced. To respond to prospective teachers, the following shows the data analysis process from the instrument: a questionnaire for prospective teachers supporting the national priority programme of STEM, STEAM, STREAM, and STEAMS education. Table 3 shows a Kaiser–Meyer–Olkin (KMO) value of 0.811 and a significant Bartlett’s test result ($\chi^2=11658.760$, $df = 171$, $p > 0.001$) Indicating that the data is suitable for factor analysis [40]. The eigenvalues of the five factors proposed from the Principal Component Analysis (PCA) are all greater than one (Figure 6 and Table 5).

Table 4

KMO and Bartlett’s test results

Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy		0.811
Bartlett’s Test of Sphericity	Approx. chi-square	11658.760
	df	171
	Sig.	0.000

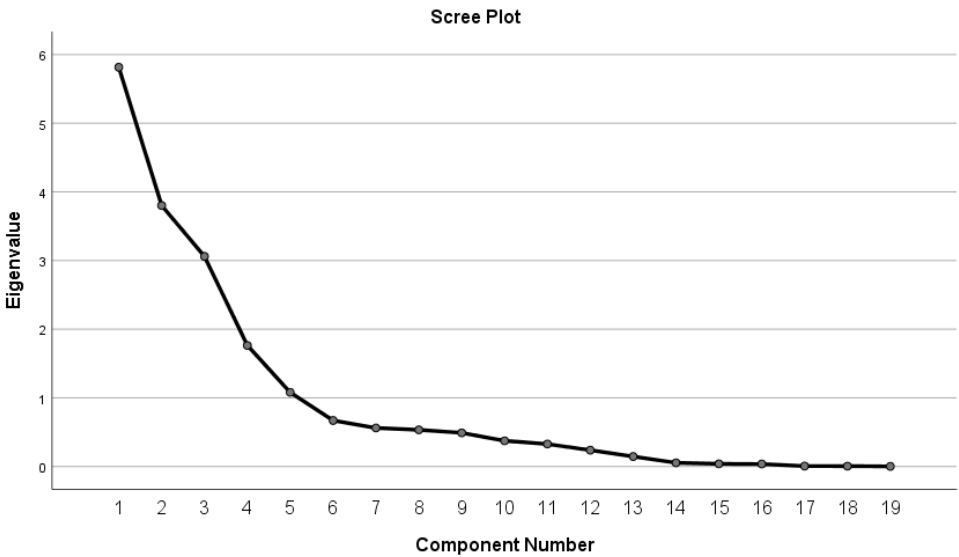


Fig. 6. Eigenvalues

Table 5

Initial eigenvalues

Component (Factors)	Initial eigenvalue		
	Total	% of variance	Cumulative, %
1	5.815	30.603	30.603
2	3.801	20.007	50.611
3	3.060	16.107	66.717
4	1.763	9.280	75.997
5	1.079	5.681	81.678

These five factors contribute 81.67% of the total variance. The factor loading of prospective teachers' responses supporting the national priority programme of STEM, STEAM, STREAM, and STEAMS education is intended to measure each factor between 0.507 and 0.907. Meanwhile, factor loadings of less than 0.400 were excluded from the analysis [40, 42]. The Cronbach's alpha values for the five factors are 0.996, 0.981, 0.893, 0.839, 0.715, and the overall Cronbach's alpha value is 0.829, as shown in Table 6.

Table 6

Loading factor

Item	Loading factors									
	E $\alpha = 0.996$		A $\alpha = 0.981$		S $\alpha = 0.893$		BU $\alpha = 0.839$		R $\alpha = 0.715$	
STEM2	0.95	20.73% VE								
STEM3	0.95									
STEM1	0.94									
STEM4	0.94									
STEAM2			0.99	20.08% VE						
STEAM4			0.98							
STEAM1			0.96							
STEAM3			0.94							
STEAMS4					0.94	16.14% VE				
STEAMS2					0.92					
STEAMS3					0.86					
STEAMS1					0.75					
BU3							0.82	14.46% VE		
BU4							0.81			
BU2							0.80			
BU1							0.66			
STREAM2									0.76	10.26% VE
STREAM1									0.72	
STREAM3									0.72	
Total variance explained = 81.67% and Overall Cronbach's alpha = 0.829										

Note. E = Engineering, A = Art, S = Social, BU = Basic Understanding, R = Religion

Based on the EFA analysis, five factors were obtained from the responses of prospective student teachers. The first factor concerns understanding of engineering pedagogy (E). The second factor concerns understanding of art pedagogy (A). The third factor concerns understanding of social pedagogy (S). The fourth factor concerns basic understanding of pedagogy (BU). The fifth factor concerns understanding of religious pedagogy (R). The R factor only has three items, because there are items with values below 0.50, so these items must be deleted [36, 43]. Items that pass the EFA analysis can be analysed further. The results show that the five factors answer 81.67% of the expected research.

Structural model

For further analysis, we used CFA analysis to determine the structural model of understanding and pedagogical elements of STEM, STEAM, STREAM, and STEAMS. We have created structural model to present the results (Figure 7).

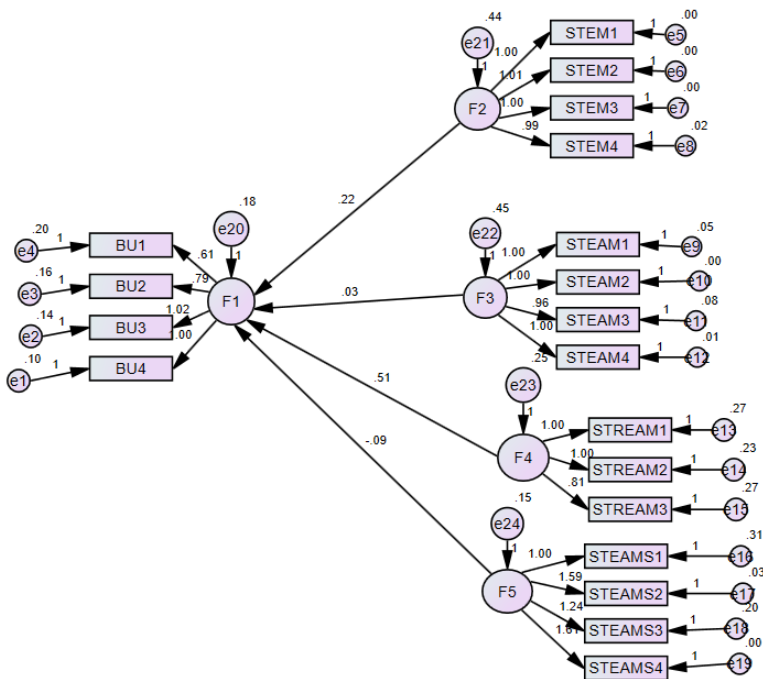


Fig. 7. Structural model

The structural model results show factor loadings in the CFA above 0.50. Ideally, factor loadings should be above 0.70 [44]. According to K. Nisa', N. Suprpto, N. Shofiyah et al. [45], factor loadings above 0.50 are still tolerable, so the convergent variables of the study can be accepted and continued. For further CFA analysis, relevant results are needed to show goodness of fit or acceptable fit [46, 47]. Table 7 shows the classification for structural indications, including goodness of fit or acceptable fit.

Table 7

Statistical CFA

Model fit summary	Score	Criteria
P values	0.000	Valid and significant
CMIN/DIF	3.884	Good fit
NFI	0.952	Good fit
TLI	0.958	Good fit
CFI	0.964	Good fit
SRMR	0.056	Good fit
RMSEA	0.084	Acceptable fit

Based on the results presented in Table 7, it is evident that the structure created with CFA data meets the good fit criteria. This means that each variable used is interconnected. Although RMSEA received an acceptable fit score, it is still tolerable, which provides an answer to the interconnection between variables [41, 48, 49]. In this context, F1 = BU is shown as the response variable, while F2 = E, F3 = A, F4 = R, and F5 = S are the manipulation variables. This shows that the pedagogical understanding of engineering, art, religion, and social studies forms the basis of understanding for prospective physics teachers to prepare for STEM, STEAM, STREAM, and STEAMS learning.

Discussion

Before proceeding with further analysis, it is necessary to determine whether the trending topics in STEM research remain relevant. Figure 8 presents data related to trending tonics in STEM and STEAM research.

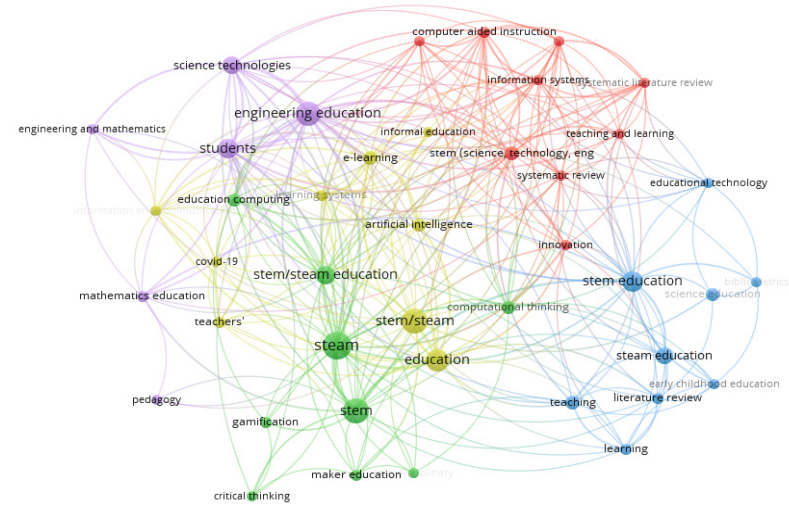


Fig. 8. Visualisation bibliometric

Figure 8 demonstrates that research on STEM and STEAM remains relevant. According to M. D. C. S. Millán and J. P. B. Arango [48], STEM-STEAM research is relevant because the elements of the approach provide a transformation from 4.0 to 5.0. Learning that employs scientific, technological, and mathematical approaches can significantly impact the development of the world. Several studies state that learning outcomes that have integrated scientific, technology-based, mathematical approaches have had an impact on the transformation of the world [30, 51, 52]. This poses a challenge for educators to integrate scientific, technology-based, mathematical approaches into learning. Therefore, our study aims to inform the readiness of prospective teachers in implementing scientific, technology-based, mathematical approaches.

Readiness of prospective student teachers

To analyse the results in greater depth regarding STEM, STEAM, STREAM, and STEAMS, it is necessary to discuss relevant pedagogical research topics and trends. From a pedagogical perspective, Table 5 explains that prospective teachers have 81.67% readiness in implementing STEM, STEAM, STREAM, and STEAMS learning. This demonstrates that prospective teachers are well prepared to implement STEM, STEAM, STREAM, and STEAMS approaches [32]. This readiness gives rise to factors E, A, R, and S, indicating that prospective teachers already have a strong understanding of its implementation. According to S. O. Rukoya, A. Widodo, and D. Rochintaniawati [53], as well as P. Wu, K. Yu, and C. Li [54], this readiness is supported by prospective teachers' understanding of STEM, STEAM, STREAM, and STEAMS learning. The strengthening of the results is supported by Table 1, which shows that prospective teachers who responded to the questionnaire were mostly in their seventh and fifth semesters. This means that the understanding and experience gained by prospective teachers led them to believe in the importance of learning through the STEM, STEAM, STREAM, and STEAMS approaches [55, 56].

Based on the sample obtained, 408 prospective teachers stated that they were ready to implement STEM, STEAM, STREAM, and STEAMS in learning. This proof is based on Table 4 of the KMO requirements and Table 5 of the initial eigenvalues, where the KMO requirements have been met and the initial eigenvalues percentage is above 50%. The KMO value meets the requirements, meaning that the sample respondents obtained, are highly valid, indicating that 81.67% of prospective teachers are ready [57, 58]. From this readiness, five factors were found to influence the readiness of prospective teachers. These five factors form the pedagogical basis for prospective teachers' readiness in implementing STEM, STEAM, STREAM, and STEAMS learning.

Structural model

The five factors obtained as shown in Table 6 consist of factors E, A, R, BU, and S, which are interrelated. According to W. Park and H. Cho [59] and Z. Lavicza, K. Fenyvesi, D. Lieban et al. [60], the development of STEM into STEAMS is necessary to adapt to the current curriculum and learning era. M. R. Bajuri, S. S. Abdul Rahim, E. H. Mohd Shahali [61], J. Ortiz-Revilla, A. Adúriz-Bravo, I. M. Greca [62], and N.

Suprpto, B.K. Prahani, T. H. Cheng [63] stated that the development of STEM is in line with the current era of society, which focuses on art, religion, and social issues. Through these basic understanding factors, prospective student teachers can process learning in accordance with the results relevant to the approach used. From these five factors, this study hopes to provide information that education in Indonesia is ready to implement STEM, STEAM, STREAM, and STEAMS approaches. Through the readiness of prospective teachers in implementing STEM, it is hoped that the quality of education in Indonesia can be improved [64].

From these factors, a structural pattern of pedagogical understanding needs to be created. This structure serves to identify the pedagogical understanding patterns of prospective teachers in the implementation of STEM, STEAM, STREAM, and STEAMS. Figure 7 shows that factors E, A, R, and S are the factors that cause BU. Understanding the elements of engineering, art, religion, and social becomes the basis of understanding in conducting learning with the STEM, STEAM, STREAM, and STEAMS approaches. According to B. S. Hughes, M. W. Corrigan, D. Grove et al. [65], by understanding the elements of engineering, art, religion, and social, prospective teachers can implement STEM, STEAM, STREAM, and STEAMS learning as expected. In its implementation, it is necessary to understand the pedagogical elements of engineering, art, religion, and social studies in STEM learning so that it is in line with the learning objectives and goals [66, 67].

The basis of STEM, STEAM, STREAM, and STEAMS development

To further elaborate on the results of this study, Figure 6, a thematic diagram illustrating the evolution from STEM to STEAM, STREAM, and STEAMS, is provided to enrich the discussion.

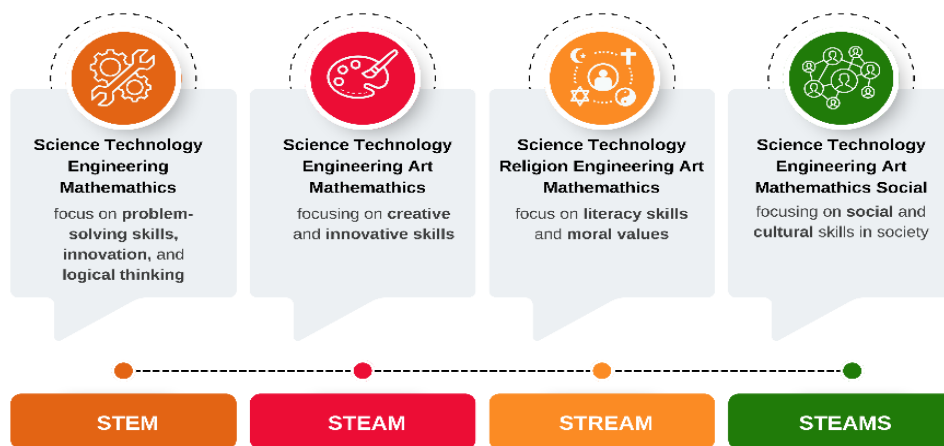


Fig. 9. Evolution thematic diagram

Figure 9 shows that the development of scientific, technology-based, mathematical approaches is not only found in STEM, but has expanded to STEAMS. The addition of art, religion, and society elements followed the development of the times. The shift from STEM to STEAM represents a transition to the skills required in the 21st century, namely creativity and innovation. The addition of art to STEAM is expected to be a strategy for enhancing students' creativity [68, 69]. The addition of the elements of religion and social is an adjustment to the era of society, which is expected to improve literacy, moral values, and socialisation skills [24, 70]. This development is recommended to be followed and its research downstreamed so that it can be adjusted to the conditions required by the transformation of the world.

Previous studies have only explained the engineering and art elements in STEM and STEAM learning. This study is unique in that it adds the elements of religion and social studies. The addition of religion and social studies in this approach is to adapt to current learning needs [24, 71]. By adding religious and social elements to science, technology, and mathematics approaches, Indonesian learning can uphold moral and social values in education [72–74]. By adding religious and social elements, this study hopes to contribute to the quality of education and support the SDGs. The inclusion of religious and social elements is an adjustment to an era of society that prioritises social and cultural aspects as well as moral values. This study is limited to the perspective of prospective teachers, which means that it has not yet reached the stage of learning implementation. Further research is recommended to implement learning using either STREAM or STEAMS.

Conclusion

Based on the research conducted, it can be concluded that prospective teachers are ready to implement STEM, STEAM, STREAM, and STEAMS learning at a rate of 81.67%. From the 81.67% of responses from prospective teachers, five factors were identified, namely BU, E, A, R, and S. These factors were then analysed in terms of pathways, which showed that they were interconnected. This interconnection forms a basic pedagogical understanding in the implementation of STEM, STEAM, STREAM, and STEAMS learning. Prospective teachers must understand the pedagogical elements of E, A, R, and S in order to have a basic understanding of the implementation of STEM, STEAM, STREAM, and STEAMS learning. These findings indicate that prospective teachers are ready to implement STEM, STEAM, STREAM, and STEAMS learning. This readiness can be achieved when prospective teachers gain a basic understanding of E, A, R, and R. Our study aims to contribute to learning by advancing scientific, technological, and mathematical approaches through curriculum transformation, as well as investigating the readiness of prospective teachers in Indonesia to implement the evolving models from STEM to STEAMS. Our study is limited to prospective teachers' responses to STEM, STEAM, STREAM, and STEAMS, and only covers certain universities that were surveyed. Further research is recommended to expand the application of STEM, STEAM, STREAM, and STEAMS approaches in Indonesian schools. In addition, further research can use compara-

tive methods to assess the effectiveness of STEM, STEAM, STREAM, and STEAMS learning that is relevant to current needs.

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А.Б. Дамарша – написание окончательного варианта рукописи, анализ данных, редактирование текста, подготовка раздела «Обзор литературы».

Н.Н.А. Насутион – разработка методологии, подготовка первоначального варианта рукописи, редактирование текста.

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