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Development and Validation of Research Skills Instruments for Pre-service Biology Teachers

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Research skills are essential for navigating the demands of the 21st century, as they allow students to become accustomed to doing critical analysis in a productive context to uncover knowledge and solutions and boost their future career prospects. However, there are still relatively few studies that develop research skills instruments. This study aims to fill the gap by developing and validating the research skills instruments. We developed and validated a research skills instrument using expert ratings of biology education and surveys. The survey was conducted on 408 respondents, namely pre-service biology teachers. Data were analyzed through descriptive analysis, Exploratory Factor Analysis (EFA), followed by Confirmatory Factor Analysis (CFA) calculated to validate and confirm the final dimensions of the newly developed instrument. This series of analysis produces 22 statement items with four dimensions, namely Embark & Clarify (EmC), composed of seven items; Find & Manage (FM), consisting of six items; Identify & Generate (IG), composed of four items; Evaluate & Communicate (EvC) consisting of five items. The CFA results match the proposed model to observational data. The study indicate that the dimension that best describes students' research skills is Evaluate & Communicate. The research skills instrument developed has an adequate internal consistency value, indicating that it can be used to assess student research skills. This study recommends a research skills instrument to evaluate students' research skills to produce graduates with scientific skills.

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Introduction

The ability to use scientific knowledge to recognize issues and explain phenomena in academic contexts in order to draw theoretical and empirical conclusions is known as research skills (Delgado & Estrada, 2022). Research abilities encompass determining pertinent research topics, developing hypotheses, gathering information, and evaluating and debating the findings (Carrió et al., 2022). Research skills foster continuous inquiry and enhance critical thinking. Research skills related to scientific thinking include evidence-based reasoning, critical thinking, epistemic maturity, contextual awareness, and basic scientific comprehension (Ain et al., 2019). Research skills are essential to develop in the learning process (George-Reyes et al., 2023; Khalaf & Alshammari, 2023). Higher education aims to give students the knowledge and abilities needed for a happy existence, including research abilities (Khalaf & Alshammari, 2023).

In higher education, research skills are essential because they give students more chances to address problems in their coursework and use their skills to produce new information (George-Reyes et al., 2023). Students require research skills to obtain accurate solutions to a specific academic subject that they are exploring. Seeking the truth using investigation activities and scientific means is necessary since intuition or previous experience alone cannot provide the truth. Therefore, it is vital to employ research skills in academics (Abbott, 2019; Damopolii et al., 2019; Heikkilä et al., 2023; Hughes, 2019; Lee et al., 2020). In higher education, research skills are essential because they give students more chances to address problems in their coursework and use their skills to produce new information (George-Reyes et al., 2023; Zapata et al., 2023); Students gain the ability to obtain, reconstruct, and share information through research skills, which help foster the growth of academic reading and writing (Castillo-Martínez & Ramírez-Montoya, 2021). In the twenty-first century, critical thinking and problem-solving abilities are crucial (Zubaidah et al., 2018). Problem-solving is essential in rapid change (Mahanal et al., 2022).

Biology students need research skills to equip practical and generic skills that produce scientific knowledge (Torres, 2018). Biology lessons are less about explaining formulas but more about explaining phenomena and experiments that require students to be able to work scientifically; therefore, students need to have research skills to produce scientific knowledge and find solutions based on a scientific approach (Hoffmeister et al., 2020; Leupen et al., 2020). Students with research abilities will be more inclined to engage in research and will be able to think critically and creatively, which is particularly important in boosting students' 21st-century skills (Heikkilä et al., 2023). Research skills can also help improve the integration of theory and practice, which has been identified as a significant educational difficulty. Research abilities are essential for establishing and expanding research-based education (Hordern, 2019). Scientific thinking encompasses a variety of research skills in higher education, including critical thinking, epistemic maturity, evidence-based reasoning, contextual comprehension, and basic scientific understanding (Ain et al., 2019).

A previous study found empirical evidence for the usefulness of developing research skills evaluation instruments (Willison & Pijlman, 2016). Effective searches that encourage acquiring research skills necessitate using reliable tools for assessing research skills (Maddens et al., 2020). The measurement issue is critical to consider, and only measurement instruments built using sound psychometrics can serve as the foundation for effective decision-making and skill assessment (Opitz et al., 2017). It is critical to analyze students' need for preparedness for researching to obtain an educational path. Hence, techniques for assessing students' research demands must be established (Meerah et al., 2012).

Limitations of research skills measurement instruments for pre-service biology teachers

There is presently limited study into developing research skills assessment instruments (Maddens et al., 2020; Meerah et al., 2012; Zapata et al., 2023). Several prior studies used skills evaluation tools created by the researchers themselves (Asghar et al., 2023; Galvez et al., 2024; Mahasneh, 2020; Mora-López & Bernárdez-Vilaboa, 2023; Perez et al., 2017), although the majority did not describe how the instruments were verified. Furthermore, it is rare to locate studies that apply psychometric or statistical testing to verify research skill tools (Zapata et al., 2023). The employment of invalid instruments can lead to excessive bias. The truth of the data is more dependent on whether or not the study instrument employed to collect it is accurate. As a result, every research instrument must be thoroughly analyzed before being conducted. Instruments are tools for collecting research data; thus, they must be reliable, accurate, and scientifically valid.

Several studies related to the development of research skills instruments have been conducted in Peru on postgraduate students (Zapata et al., 2023), Malaysia on doctoral students (Meerah et al., 2012), Belgium for grade 11 and 12 students (Maddens et al., 2020), China on nursing students (Qiu et al., 2019), the United States on lecturers and doctoral students (Swank & Lambie, 2016), Spain and Columbia on nursing students and instruments developed specifically on research (Corchon et al., 2010; Mallidou et al., 2018). Articles that review the development and validation of research skills instruments for pre-service biology teachers through exploratory and confirmatory factor analysis are quite limited. This research intends to fill a gap in prior studies.

Conceptual Framework: Research Skills Development Paradigm

There is a need to create research skills assessment instruments that encompass all theoretical elements of domain-specific research skills (Maddens et al., 2020). Instruments with relevant indicators are required to assess the capacity produced during higher education (Zapata et al., 2023). As a result, a new instrument for this specific target group was designed using Willison and Pijlman's (2016) Research Skills Development (RSD) paradigm, meeting the requirements of internal consistency reliability, content, and construct validity.

The RSD framework refers to research processes in both academic and multidisciplinary contexts as "facets" of research. The RSD aspect describes what the researcher does. The RSD aspect provides a complete perspective on the research process many scientific disciplines share. Academics employ the generic description of RSD to operationalize it as a descriptor particular to scientific disciplines and sensitive to the study situation (Willison & Pijlman, 2016). The six facets of the RSD framework are as follows: 1) Embark & clarify: the investigator initiates the study, ascertains and elucidates the information that is required, all the while keeping social, cultural, and ethical factors in mind; 2) Find & generate: Using the proper methodology, the researcher locates information and generates research data that is pertinent to the 3) Evaluate and reflect: Researchers assess data and information and consider the complete procedure that was employed. 4) Organize and manage: Researchers oversee both individual and group research procedures, as well as the organization of information and data. 5) Analyze and synthesize: To create comprehensible understanding for both individuals and teams, researchers synthesize new knowledge and analyze information and data. 6) Communicate and apply: Researchers must pay attention to ethical, cultural, and social issues

when they write, speak, and carry out the process of comprehending and applying research. They also must respond to feedback (Torres, 2018; Willison & Pijlman, 2016).

Research skills development is facilitated by incorporating the RSD framework into the fundamental design of research activities (Mataniari et al., 2020). The RSD conceptual framework is intentionally wide, allowing academics to adjust it to their context. A broader framework has the advantage of being more adaptable to various scenarios (Willison & Pijlman, 2016). The RSD framework is valuable for creating research-focused approaches and learning experiences (Gyuris, 2018). According to the literature study, few studies have created a questionnaire using the RSD framework for student teachers, particularly pre-service biology teachers.

The Rationale of the Study

According to the findings, it is critical to address the requirement for building research skills assessment instruments setting utilizing the RSD framework. This study aims to create and evaluate an evaluation tool in the form of a research skills questionnaire using exploratory and confirmatory factor analysis.

This study aims to answer the following research questions: (1) what are the findings from the validation of instruments used to measure research skills among students preparing to become biology teachers? (2) how do the findings of confirmatory and exploratory factor analyses shape the dimensions of research skills? The creation of a trustworthy tool to assess pre-service biology teachers' research abilities is the expected result of this study. The outputs of student research skill assessments can be taken into account when creating graduate competence requirements, curricula, learning methods, models, and assessments of learning outcomes in biology pre-service teachers.

Method

The research skills assessment instrument developed was in the form of a questionnaire. The research skills questionnaire was developed in four stages. The first stage is a literature review and item formulation. The second stage involves expert judgment. The third stage is exploratory factor analysis (EFA). The fourth stage is testing the construct validity and internal consistency of the questionnaire produced through confirmatory factor analysis (CFA) (Marlina et al., 2023; Suwono et al., 2022).

First stage

At this stage, a literature search was collected from national and international journal articles used as input for this research. The literature review also focused on instruments for assessing research skills in the field of learning. Based on the results of the literature review, research skills consist of six aspects, namely 1) embark & clarify, 2) find & generate, 3) evaluate & reflect, 4) organize & manage, 5) analyze & synthesize, 6) communicate & apply (Willison & Pijlman, 2016). Based on the six aspects of research skills proposed by Willison and Pijlman (2016), a 25-item research skills questionnaire was prepared. The embark & clarify aspect consists of 5 items, the find & generate aspect consists of 6 items, the evaluate & reflect aspect consists of 4 items, the organize & manage aspect consists of 3 items, the analyze & synthesize aspect consists of 4 items, the communicate & apply aspect consists of 3 items. The questionnaire was prepared using a Likert scale with five response choices

consisting of 1 = Strongly disagree, 2 = Disagree, 3 = Neither agree or disagree, 4 = Agree, 5 = Strongly agree.

Second stage

Face and content validity are evaluated through expert validation. An indicator's face validity is determined by how rational its arrangement, structure, sequence, and evaluation format appear (Creswell, 2012). The instrument's completeness, simplicity, relevance, and clarity are evaluated for content validity (Rodrigues et al., 2017). Three top Biology Education lecturers from various Indonesian universities were requested to critique the original draft of the research skills evaluation tool that had been developed. Content validity was examined both objectively and qualitatively. Experts were asked to assess the research skills questionnaire developed with five answer choices. Each expert was also asked to provide suggestions and input to improve the questionnaire being developed. Validation results from experts are tested for validity and reliability.

Each expert uses the research skills questionnaire to evaluate parts of the research skills indicators, constructs, and language use. Face and content validity results determine how much experts agree on the instrument's presence and substance (Table 1). Validity is also checked to ensure the questionnaire's contents are readable, accurate, and appropriate. Each expert also suggested and commented on ways to improve the questionnaire that had been developed.

Table 1 Results of expert validation of the research skills questionnaire

No	Aspect	Statement Items	Validation Score			
			Expert 1	Expert 2	Expert 3	Average Percentage (%)
1.	Indicator of Research Skills	a. The questionnaire's indicators demonstrate research skills tracking.	5	4	5	93.33
		b. The statements accurately explain each indicator of research skills.	5	5	5	100.00
2.	Construct	c. Use operational statements.	5	4	5	93.33
		d. Instructions for completing the questionnaire are clear.	4	4	4	80.00
		e. Provides the criteria for the answer choices.	4	3	3	66.67
3.	Language Usage	f. Formulation of communicative statement sentences.	5	4	4	86.67
		g. Statements are written in proper Indonesian.	5	4	4	86.67
		h. The statement items on the questionnaire are clear.	5	5	5	100.00
		i. The statement items in the questionnaire are easily understandable.	5	5	5	100.00
	Average Percentage (%)		95.56	84.44	88.89	89.63

The average percentage of the experts' approval rate of 89.63% is in the valid category. No item gets a score below 3, which means that the experts agree on the form and content of the instrument. The experts also provided suggestions and comments for improvement on the

developed research skills questionnaire (Table 2.).

Table 2 Suggestions and comments on improving the research skills questionnaire

No	Suggestions and comments	Revision
1.	Correction of writing	The writing has been corrected.
2.	The sentence predicting or formulating a hypothesis in the statement "I can predict or formulate a research hypothesis" is the same or different.	Only the sentence formulating a hypothesis is used so that respondents are not confused. Thus, it becomes "I can formulate a research hypothesis."
3.	Please provide research objectives.	The research objective has been added to the introductory section of the questionnaire.

Third stage

Participants

The study participants comprised 408 (EFA= 120 participants and CFA= 288 participants) biology education students from three universities in Riau Province, Indonesia. There were 317 students at Riau University, 64 at Riau Islamic University, and 57 at Lancang Kuning University. The sample of three colleges included 8.6% male students (n=35) and 91.4% female students (n=373). The number of responders surpassed the minimum required for factor analysis (Dörnyei & Taguchi, 2009; Tabachnick, B & Fidell, 2007). Two categories of data were created from the participants. In the first group, data from 120 participants were used for EFA testing and 288 participants were used for CFA testing.

Data collection

This study's data was gathered using an online survey administered on the Google platform between December 2023 and February 2024. Academics from Riau Province, Indonesia, including Riau University, Riau Islamic University, and Lancang Kuning University, provided Google Forms. Each university's teachers then distributed the Google Form link to students.

Assessing Data Reduction and Content Validity

By looking at the responses provided by students to the distributed questionnaire, content validity and data reduction were evaluated. Descriptive statistics are used to analyze the scores obtained consisting of the mean (M) and standard deviation (SD) and total item correlation (Pearson product-moment correlation coefficient) were used to examine the scores. By identifying related things and eliminating those with ambiguous or similar meanings, EFA reduces the number of items. Exploratory factor analysis is an evaluation that seeks to uncover several factors that explain the items, followed by confirmatory factor analysis to ensure the instrument's validity (Zapata et al., 2023).

Sample adequacy was assessed using the Kaiser-Meyer-Olkin (KMO) test before EFA. Next, the Bartlett test was employed to assess the observed correlation matrix. The dimensions and item components of the questionnaire were then determined using EFA. Eigenvalues > 1 are used to determine the total number of generic domains. Verimax rotation with Kaiser normalization is the technique employed. If the Rotated Factor Loading was less than 0.50 or suggested cross-loading in this study, item reduction was done. Furthermore, any dimension with fewer than two items was eliminated; all dimensions now have a minimum of three items.

Fourth stage

Using confirmatory factor analysis, this step precisely determines the general domain of the number of items produced from the data reduction phase. Model appropriateness is evaluated using maximum likelihood estimation in accordance with the covariance matrix. The chi-square goodness test (X2/df), the Tucker-Lewis index (TLI), the goodness-of-fit index (GFI), the adjusted goodness-of-fit index (AGFI), the standardized root mean square residual (SRMR), and the comparative fit index (CFI) are a few frequently used data fit indices (Saefi et al., 2020). Generally speaking, $\chi 2/df \leq 3.00$, RMSEA of ≤ 0.08, and SRMR of ≤ 0.10 are used to determine model fit (Schumacker & Lomax, 2010; Tabachnick & Fidell, 2007); and the GFI, AGFI, CFI, and TLI are near 0.90, indicating an acceptable fit, whereas the values ≥ 0.9 and > 0.80 indicate good and acceptable fits, respectively (McCoach et al., 2013). Cronbach's alpha, composite reliability (CR), and average variance extracted (AVE) were also checked to ensure the internal consistency of the questionnaire items. Values for Cronbach's alpha be ≥ 0.6, CR≥ 0.7, and AVE≥ 0.5.

Result

The Pearson correlation score showed a significant and positive link, while the standard deviation showed that the score fell short of the 2.5 mean. The descriptive analysis's (Table 3) findings indicate that each item's mean score ranges from 3.4 to 4.0, with a standard deviation of 0.67 to 0.85. To ascertain whether the items have about the same standard deviation and contribute equally to the overall scale score, M and SD are utilized. The range of the Pearson product-moment correlation coefficient score is 0.596 to 0.797. One type of correlation test that assesses the degree of association between individual item scores and the final result is the Pearson Product Moment Correlation. The correlation score between Pearson product-moment. The Pearson Product-moment Correlation Score indicates a correlation coefficient value ranging from "fairly strong" to "strong".

Table 3 Results of descriptive statistical analysis

Item	Mean (M)	Standard Deviation (SD)	Pearson correlation (r)
1	3.79	0.69	0.596**
2	3.75	0.66	0.681**
3	3.66	0.67	0.714**
4	3.83	0.72	0.672**
5	3.78	0.74	0.639**
6	4.05	0.69	0.663**
7	3.90	0.67	0.684**
8	3.52	0.75	0.666**
9	3.48	0.70	0.712**
10	3.66	0.69	0.686**
11	3.69	0.68	0.727**
12	3.60	0.70	0.741**
13	3.67	0.72	0.769**
14	3.77	0.71	0.688**
15	3.73	0.75	0.770**
16	3.74	0.77	0.693**
17	3.72	0.73	0.793**
18	3.62	0.75	0.659**
19	3.67	0.73	0.793**
20	3.67	0.72	0.793**
21	3.57	0.68	0.768**
22	3.53	0.68	0.755**
23	3.71	0.76	0.797**
24	3.57	0.85	0.733**
25	3.80	0.72	0.745**

There are a total of 25 questions in the research skills questionnaire that may be calculated using EFA. According to Kaiser's (1970) standards, the Kaiser-Meyer-Olkin (KMO) sample adequacy of 0.94 is classified as "very good" based on the EFA results. The results of Bartlett's test yield 0.000, indicating that the data satisfies the EFA requirements. MSA (anti-image) has a value of more than 0.5. The EFA results identified four dimensions with a total variance of 65.916% (within the recommended range). Except for item 8, all items have factor loading values greater than 0.5. The EFA results also revealed two cross-loading items, item 12 and item 13; items 12 and 13 significantly load on more than one dimension (cross-loading), reducing both items. Cross-loading can make factor interpretation more complex because it shows that the item does not purely measure one dimension or construct but has a relationship with other dimensions. In addition, item 8 was also reduced because it had a factor loading below 0.50. Factor loading below 0.50 indicates that the item has a weak relationship with the identified dimension; the item is often considered not strong enough to contribute to a particular dimension. Low loading can also indicate that the item does not measure the same construct well or consistently. Three items were reduced, namely items 8, 12, and 13. Table 4 displays the factor loadings of 22 statement items distributed across four dimensions.

Table 4 Final EFA results for 22 items (n=120)

Dimension	Items	Components			
		1	2	3	4
Dimensions 1	24	0.788			
	19	0.704			
	25	0.676			
	15	0.611			
	20	0.592			
	23	0.554			
	9	0.539			
Dimensions 2	17		0.684		
	18		0.647		
	16		0.635		
	7		0.626		
	4		0.597		
	21		0.581		
Dimensions 3	10			0.819	
	11			0.676	
	14			0.604	
	22			0.519	
Dimensions 4	1				0.802
	2				0.659
	3				0.592
	5				0.586
	6				0.519
Eigenvalue		12.944	1.333	1.182	1.020
Percentage of variance		51.775	5.331	4.729	4.081
Cumulative		51.775	57.106	61.835	65.916

A total of 22 EFA result items with four dimensions (Table 5.) were further analyzed with CFA.

Table 5 Dimensions of research skills (developed dimensions)

No	Dimensions	Items
1.	Evaluate & Communicate	1. I can determine the right instrument to obtain the required information or data. 2. I can reflect deeply to improve the procedures I use 3. I can critically analyze the information/data obtained. 4. I can identify and implement problem-solving strategies 5. I can write scientific reports. 6. I can communicate knowledge verbally and scientifically. 7. I can apply my understanding to provide feedback during class discussions.
2.	Find & Manage	8. I can develop research questions based on current problems/issues. 9. I can find relevant information to the problem being researched. 10. I can manage the time allotted to complete the research procedure. 11. I can organize procedures in experiments or studies. 12. I can categorize and organize data in tables, graphs, and diagrams. 13. I can give a thorough explanation of the data evidence acquired.
3.	Identify & Generate	14. I can generate data through appropriate procedures. 15. I can identify appropriate data based on the required criteria. 16. I can assess process errors or the information I produce. 17. I can synthesize new understanding based on the data acquired to develop a logical understanding.
4.	Embark & Clarify	18. I can clarify existing problems/issues. 19. I can develop research questions based on current problems/issues. 20. I can clarify existing problems/issues. 21. I can formulate a research hypothesis. 22. I can look for information from various literary sources.

The results of the CFA also show that four dimensions using a correlated model satisfy the appropriateness requirement (Figure 1). The suggested model and observational data are matched by the CFA results (RMSEA=0.072; SRMR=0.023; CFI=0.928 NFI=0.886; AGFI=0.827 TLI=0.918; PNFI= 0.779). 2.482 ≤ 3 is the chi-square goodness score (X2/df). The fit criteria are indicated by the CFI score of 0.923, which is higher than 0.90. Furthermore, the fit criteria are indicated by the RMSEA value of 0.072, which is less than 0.08. Fit criteria are shown by an SRMR score of 0.023 ≤ 0.10. The NFI score of 0.886 exceeds 0.80, indicating acceptable standards. The AGFI score of 0.827 indicates satisfactory standards. The TLI score of 0.918 exceeds 0.90, indicating the fit requirements. The PNFI score of 0.779 indicates the fit requirements. Each item has appropriate requirements because the factor loading exceeds 0.35.

Table 6 22 items from the four dimensions of research skills

Dimensions/item	Criteria			
	Λ	CR	AVE	CA
EvC				
EvC1	0.702	0.94	0.576	0.904
EvC2	0.748			
EvC3	0.783			
EvC4	0.810			
EvC5	0.757			
EvC6	0.739			
EvC7	0.771			
FM				
FM1	0.729	0.93	0.559	0.881
FM2	0.707			
FM3	0.657			
FM4	0.809			
FM5	0.736			

Dimensions/item	Criteria			
	Λ	CR	AVE	CA
FM6	0.829			
IG				
IG1	0.746	0.94	0.565	0.835
IG2	0.759			
IG3	0.672			
IG4	0.813			
EmC				
EmC1	0.717	0.92	0.531	0.845
EmC2	0.752			
EmC3	0.791			
EmC4	0.751			
EmC5	0.620			

In order to determine whether the measurement scale is effective for a variety of respondents, the researcher also examined internal consistency. Each dimension was measured using three different metrics: Cronbach's alpha (CA), average variance extracted (AVE), and composite reliability (CR) (Table 6). According to the grain quality value (λ), every factor has a value higher than 0.50. This demonstrates that the latent variables of the construct are sufficiently reflected by the observable variables (Tabachnick & Fidell, 2013). The Cronbach's alpha test yielded encouraging findings, ranging from 0.881 to 0.904, on 22 items with four dimensions. As a result, the total value was 0.866. The created research skills questionnaire has excellent reliability across all domains and metrics.

The association between the dimensions formed was also established by this research (Table 7). According to the findings, there was the greatest connection (0.954) between EvC and IG, and the lowest correlation (0.869) between IG and EmC. The model of linked components presented in this study serves as the foundation for these estimations. There is a noteworthy positive association among the four dimensions generated by the CFA model.

Table 7 Correlation of the four dimensions of research skills

	EvC	FM	IG	EmC
EvC	1.000			
FM	0.940**	1.000		
IG	0.954**	0.951**	1.000	
EmC	0.891**	0.907**	0.869**	1.000

Note:**p<0.01

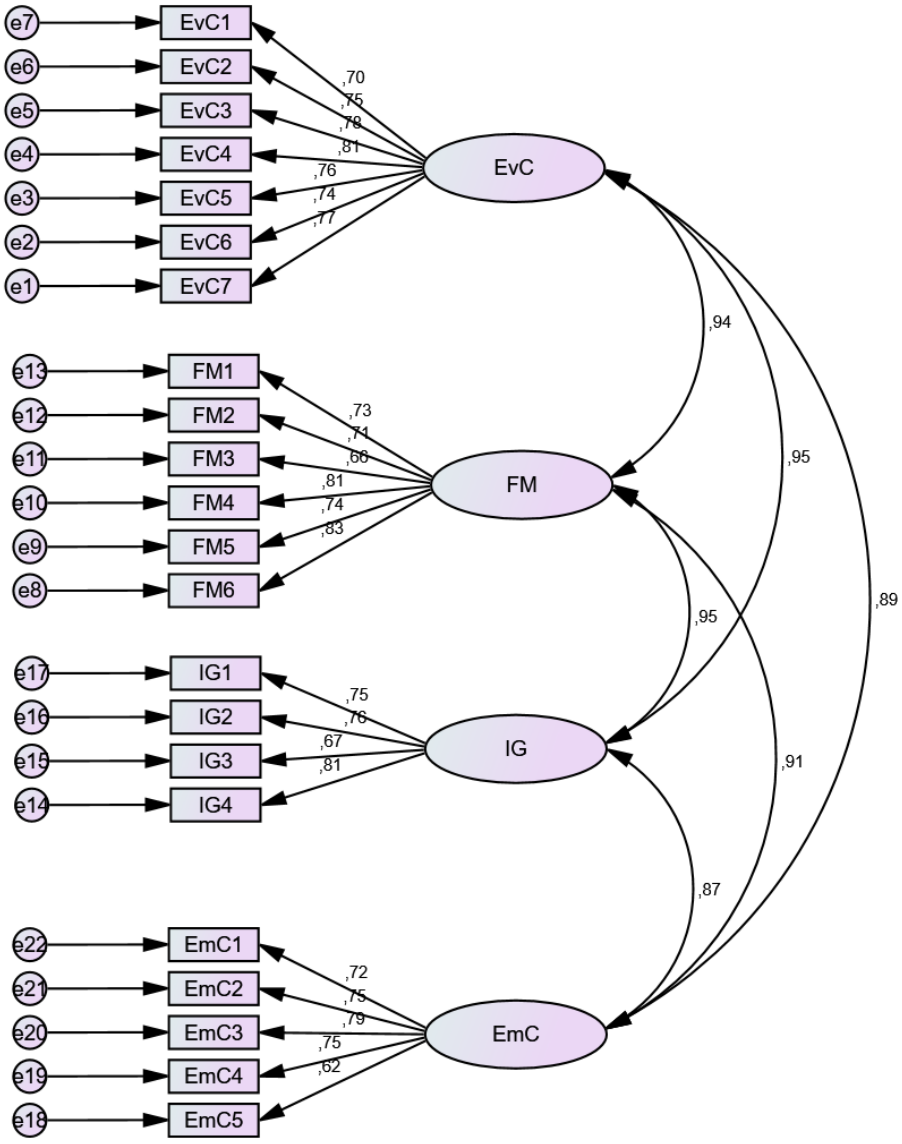

Figure 1. Confirmatory factor analysis with the correlated model (n=288)

Discussion

The aspect of research skills used for instrument development is broad enough to describe the research skills possessed by students so that they can assess students' research skills accurately. These aspects fulfil the need to measure students' research skills.

Discussion on the Validity and Reliability of Research Skills Instrument

The researchers calculated psychometric analysis using EFA and CFA in this study. Researchers have ensured that the sample is categorized as adequate, according to Meyers et al. (2017). This research involved 408 respondents, namely biology education students at three state and private universities in Riau, Indonesia. The final number of items resulting from this research was 22 from the initial 25 items (88%). The larger the research sample size, the more reliable the statistical test will be. The factor loading values of the statement items in

the questionnaire created for this study are all more than 0.50. This demonstrates that the latent variables of the construct are sufficiently reflected by the observed variables. In comparison, Maddens et al. (2020) research reveals that certain items have extremely low factor loading values of less than 0.50. One item related to problem identification, five items related to statements, five items related to evaluating evidence, two items related to creating evidence, two items related to concluding, and seven items related to communication and research were removed from the model because their factor loading values were less than 0.50. Item analysis is done to find out why these items have low factor loadings (item analysis has found one or more issues with these items, such as low item correlation scale and/or very low or very high p-value). Nevertheless, eliminating these items does not compromise the content's validity.

Every dimension's internal consistency analysis reveals an AVE value of more than 0.5 (0.531-0.576) and a CR value of more than 0.6 (0.92-0.94). Every item has a Cronbach Alpha coefficient of greater than 0.800 (0.835-0.904). The internal consistency analysis's findings demonstrate that the reliability of every instrument item satisfies the requirements and is approved (Meyers, 2016). This finding is similar to the results of research in Peru, which reported the research skills instrument items it developed with a Cronbach Alpha coefficient of 0.89 (Zapata et al., 2023), research in China on nursing students reported one factor with 24 items and a Cronbach Alpha coefficient of 0.98 (Qiu et al., 2019), research at Columbia reported the research skills instrument items it developed with a Cronbach Alpha coefficient of 0.877 (Mallidou et al., 2018). Research in Belgium on 11th and 12th-grade students reported a reliability coefficient for the research skills instrument items they developed 0.78.

The instrument created for this study contains all dimensional statements that are appropriate for use and have good internal consistency. The research skills instrument that was created can be used to measure students' research skills in future studies, taking into account each dimension. To put it briefly, student research skills, particularly in Indonesia, can be described using the four dimensions of research skills.

Discussion on the Dimensions of Research Skills Instrument

The research results show that respondents formed four dimensions of research skills, initially with six dimensions of research skills (Willison & Pijlman, 2016). The four dimensions formed are Embark & clarify, Find & manage, Identify & generate, and Evaluate & communicate. The four dimensions formed are dimensions that are clearer and do not overlap. The separation of the research process into six different dimensions based on the initial framework is artificial because these dimensions often occur simultaneously and overlap (Willison & Pijlman, 2016). The four dimensions offered in this research describe the dimensions involved in the research process more explicitly.

The EFA results show that some items in the initial dimension merge with items in other dimensions. Items from one dimension can merge with items from others when there is a significant correlation. The CFA results have confirmed that the factor structure generated in this study is valid. The four dimensions formed will be explained in detail as follows.

Evaluate & Communicate Dimension

The results of this study gave rise to the evaluate and communicate dimension, which came from a combination of items in the evaluate and reflect dimension with items in the communicate and apply dimension, so researchers gave rise to a dimension with the name

evaluate and communicate. The evaluate & communicate dimension in the study is defined as the ability of students to determine the right instrument to obtain the necessary information or data, reflect deeply on the procedures used, critically analyze the information or data obtained, apply problem-solving strategies, make reports through scientific writing, communicate knowledge orally, apply understanding to provide feedback during class discussions. The evaluate and communicate dimension has an impact on how well students are able to conduct research. This is in line with the conclusions of Heikkilä et al., (2023) and Noguez and Neri (2019), who found that it is extremely beneficial to involve students in the process of learning basic research skills from the outset. These skills include searching for information in credible sources, critically analyzing existing knowledge, and honing oral and written communication skills so that they can present their findings. Finding information is closely related to reading activities, through reading activities, students are trained in analyzing, synthesizing, and justifying information contained in a text (Zubaidah, et al., 2018). Students who can access, analyze, and synthesize relevant information to explore problems will be able to build solutions (Mahanal et al., 2019).

According to psychometric analysis, the evaluation & communication dimension has the most prevalent distribution of statement items, with seven items total. Based on these results, the evaluation & communication dimension has the most contribution, accounting for 31.8% of the total 22 statement items that connect with this dimension. The evaluation & communication dimension includes activities to determine, evaluate and criticize the credibility of sources, information, data and ideas as well as activities to present research processes, knowledge, and implications (Willison & Pijlman, 2016). Research skills include searching, synthesizing, and analyzing data appropriately (evaluating) and communicating the results of the analysis using a specific scientific study writing format. (Hendriarto et al., 2021; Kelly, 2019). The evaluate & communicate dimension relates to listening and responding to feedback, and it is added with the explanation that communication is a two-way process. This will provoke educators to think further, not only providing feedback but also paying attention to what students do with the feedback (Boud & Molloy, 2013) and how students themselves can provide feedback from their peers and reflect for self-improvement (Willison & Pijlman, 2016). Students who conduct research will gradually improve their research skills by completing a variety of assignments, including information search, methodology, basic analysis, data collection, and manuscript writing (Zapata et al., 2023).

Previous research reported that students' perceptions of research skills were low in the statistical analysis and discussion of research results sections (Awodoyin et al., 2021; Meerah et al., 2012; Zapata et al., 2023). These findings could be due to several factors, including ineffective teaching of the use of research methods by lecturers (Peiró-Signes et al., 2021) and students who do not achieve adequate learning will adopt ineffective research methods (Brezavšček et al., 2017). Therefore, it is necessary to pay attention to the evaluate & communicate dimension, which in this research includes statement items that explore students' ability to determine appropriate instruments to obtain accurate data, carry out in-depth reflection to improve the research procedures used, critically analyze the information or data obtained, apply problem-solving strategies correctly.

Find & Manage Dimension

The second dimension produced in this study is find & manage, which comes from a combination of several items in the find & generate dimension with items in the organize & manage dimension so that the researcher can raise a dimension with the name find & manage.

The find & manage dimension in this study is the ability of students to formulate research objectives based on existing problems or issues, find information relevant to the problem under study, provide a comprehensive explanation of the data obtained, manage the time given in the research process, organize procedures in experiments, compile data in tables or graphs or diagrams. According to Zapata et al. (2023), developing the ability to select and find scientific information is important in carrying out academic research work because it relies on knowledge based on scientific evidence. The ability to organize learning activities systematically also plays a role in improving research skills (Bueno, 2017; Perez et al., 2017; Rodríguez et al., 2019). Research skills can be improved through students' activities to find relevant information by reading literature on previous research results to find a comprehensive explanation (Meissner & Shmatko, 2019).

Identify & Generate Dimension

The third dimension produced in this study is identify & generate which comes from a combination of several items in the analysis & synthesis dimension with several items in the find & generate dimension so that the researcher raises a dimension with the name identify & generate. The identify & generate dimension in this study is the ability of students to generate data through proper procedures, identify appropriate data based on the criteria needed, assess process errors or information generated, and synthesize new understanding based on the results of the data obtained to produce logical understanding. The identification & generation dimension relates to students' skills in identifying or an action carried out by several processes such as searching, finding, researching, and recording data and information about something and producing knowledge. Research skills are skills related to searching for data, understanding, and applying data and information in various opportunities and contexts (Bandaranaike, 2018). Research skills refer to how knowledge is produced, maintained, and reproduced (Heikkilä et al., 2023)

Embark & Clarify Dimension

The fourth dimension produced in this study is the embark & clarify dimension. The embark & clarify dimension in this study is the ability of students to start research as seen from the competence of identifying a problem, formulating research questions based on the problem, clarifying problems/issues, formulating research hypotheses, and seeking information from various sources of literature by the definition of Willison & Pijlman (2016) that the Embark & Clarify dimension is defined as the ability to respond or initiate directions and clarify and consider existing problems or issues.

The results of the variance percentage show that the embark & clarify dimension has the smallest variance percentage. This shows that the embark & clarify dimension is less dominant in measuring research skills. One aspect of research skills that requires attention is the embark and clarify dimension, particularly in Indonesia. The ability of students to identify problems and clarify existing problems is important; this is the opinion of Tajuria et al. (2024) that in order for universities to successfully meet the demands of the expanding education and workforce ecosystem, they must acquire the skills necessary to recognize issues and explain academic phenomena. Research in an academic setting starts with curiosity. It continues with answering existing questions and problems through identification activities, and it is important to know the right way to find solutions until the results obtained can be communicated properly (Carberry et al., 2021).

Theoretical and practical implications

In general, the instrument produced from this study can significantly contribute as a framework for analysing the research skills of prospective biology teachers. The findings of new measurement dimensions can enrich concepts and definitions related to research skills. The findings may also lead to the updating or redeveloping of existing theories in the relevant literature. For example, these new dimensions may help to further define or classify research skills in more detail.

The results obtained from measuring students' research skills through the measurement instruments produced can be considered for curriculum reformulation and learning processes that can optimize student research skills. Furthermore, knowing how well biology education students conduct research can serve as a benchmark for creating graduate competency standards and assessing the success of biology education study programs in Indonesia. Research abilities can enhance learning outcomes, help students comprehend a problem, and facilitate better decision-making (Ain et al., 2019). Furthermore, the research skills that students acquire may serve as the foundation for a description of their ability to solve problems using the scientific method. The reason why students conduct research is to find the correct solution to a specific academic problem they are studying. Finding the truth necessitates using a scientific approach since it requires relying on intuition or past knowledge. For this reason, it is critical for academics to use their research skills (Lee et al., 2020; Mallidou et al., 2018).

The findings of this study reveal that the evaluate & communicate dimension is the dominant aspect of students' research skills. Pedagogical approaches can be improved by systematically emphasising the development of these skills. Lecturers can design learning activities focusing more on teaching, practising critical evaluation, and effective communication. Strengthening evaluation skills through active learning, such as case studies, group discussions, or research projects can be implemented. This helps students hone their ability to evaluate various sources of information, arguments, or data. Scientific communication can be trained through report writing, presentations, and discussions. Students need in-depth training in developing clear, structured, and persuasive scientific writing skills. Providing research projects based on collaboration between students or with external stakeholders (e.g. industry or community) can strengthen the evaluation and communication dimension. This collaboration not only improves evaluation and communication skills but also teaches the importance of teamwork and adaptation to multiple perspectives. By appropriately addressing the evaluation and communication dimension in a pedagogical approach, educational institutions can prepare students to have more competent research skills and contribute significantly to their discipline to solve existing problems.

Research is a challenge that must be faced by Education to encourage the development of a creative, critical, and independent human who can prioritize alliance formation with national and international institutions that become the research development and innovation model that can utilize their experience in management and development of education strategy, training, and capacity enforcement of lecturers, researchers, trainers, and students. Besides, the academic program's curriculum must be improved in the cases related to the student's research (Mallidou et al., 2018; Zapata et al., 2023). Research skills appear to play an independent role as a tool for creating new knowledge, which is critical because students are expected to develop into professional agents who are independent and active in utilizing the knowledge and skills acquired through their work, allowing for better decision-making (Ain et al., 2019; Heikkilä et al., 2023).

Conclusion

This research has built a reliable research skills assessment instrument. The instrument for assessing research skills that was developed has an acceptable internal consistency value, making it suitable for measuring the research skills of students. This instrument can be used and is significant in measuring skill dimensions. Regarding EFA testing, four dimensions of research skills were produced with 22 statement items, namely Embark & Clarify (5 items), Find & Manage (6 items), Identify & Generate (4 items), and Evaluate & Communicate (7 items). To verify the accuracy of the dimensions derived from the EFA results, we test them using CFA. The observed data were fitted to the proposed model by the CFA results. According to the study's findings, the dimension that best describes students' research skills is evaluate and communicate.

Based on all the analyses that have been done, it is suggested that this instrument be used in educational research going forward. It can be used to assess students' research abilities by educators and other researchers. The government or educational institutions may decide to reformulate the curriculum to meet the demands of education in the twenty-first century by using the instrument created in this study as a foundation.

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Ethics Statements

The study was conducted in accordance with the strictest ethical guidelines, according to the authors.

Conflict of Interest

The writers have declared no conflicts of interest

Informed Consent

All respondents in this study have agreed to participate in all research activities.

Data availability

If you contact the corresponding author, you can obtain the data that supported the findings and conclusions.

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Appendix.

Tabel 1 Items in the final instrument

Items	Scales				
	Strongly disagree	Disagree	Neither agree or disagree	Agree	Strongly Agree
Embark and Clarify					
• I can clarify existing problems/issues. • I can develop research questions based on current problems/issues. • I can clarify existing problems/issues. • I can formulate a research hypothesis. • I can look for information from various literary sources.					
Find and Manage					
• I can develop research questions based on current problems/issues. • I can find relevant information to the problem being researched. • I can manage the time allotted to complete the research procedure. • I can organize procedures in experiments or studies. • I can categorize and organize data in tables, graphs, and diagrams. • I can give a thorough explanation of the data evidence acquired.					
Identify and Generate					
• I can generate data through appropriate procedures. • I can identify appropriate data based on the required criteria. • I can assess process errors or the information I produce. • I can synthesize new understanding based on the data acquired to develop a logical understanding.					
Evaluate and Communication					
• I can determine the right instrument to obtain the required information or data • I can reflect deeply to improve the procedures I use • I can critically analyze the information/data obtained. • I can identify and implement problem-solving strategies • I can write scientific reports. • I can communicate knowledge verbally and scientifically. • I can apply my understanding to provide feedback during class discussions.					

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